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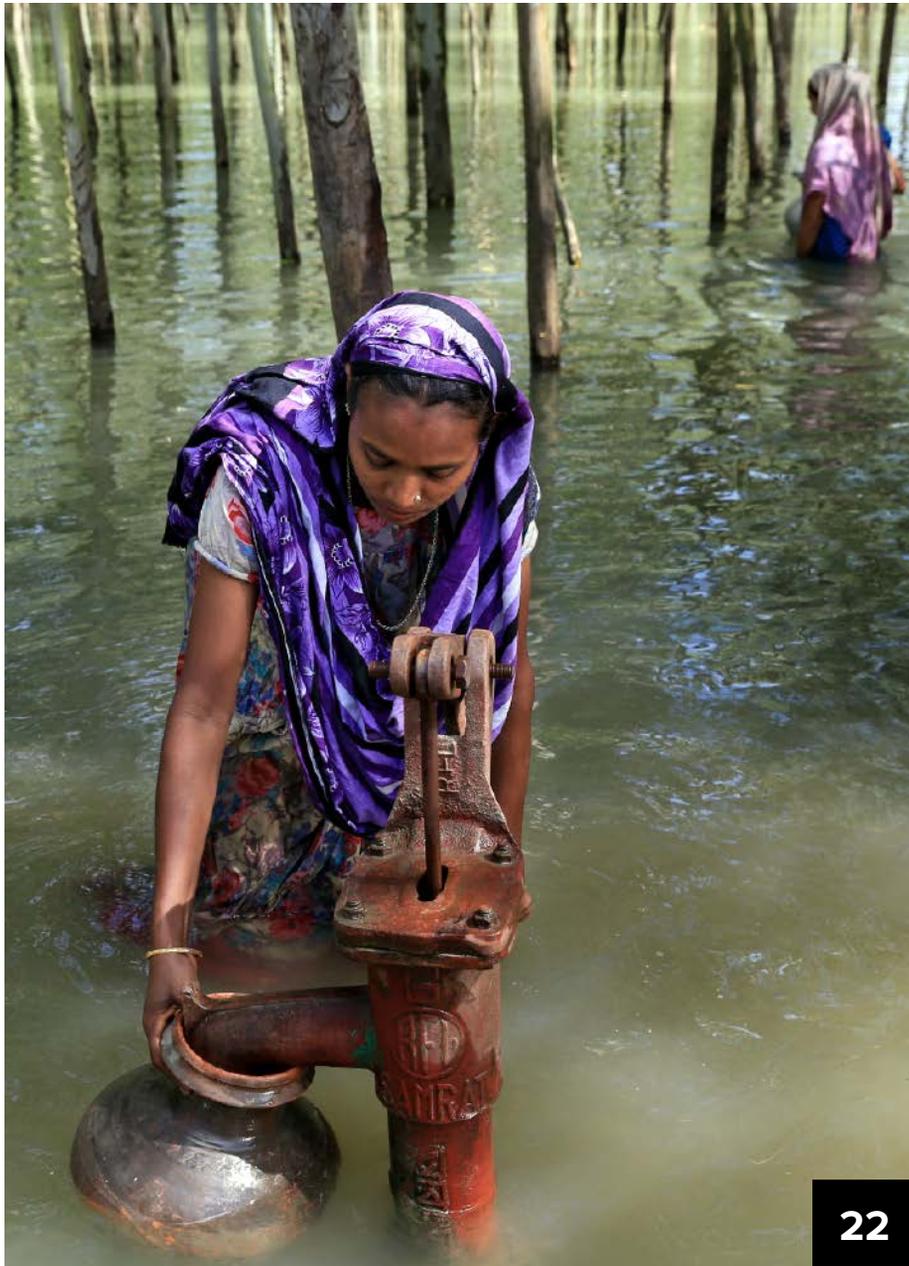


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A woman in Bangladesh's Jamalpur district pumps water in a flooded field. Credit: Mushfiqul Alam/ NurPhoto/Getty Images.

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Christine W. McEntee, Executive Director/CEO



An Aurora of a Different Color



Krista Tinder

A rare aurora-like event, pictured here, paints a green and purple streak across the sky, from bottom left to top right. Called a Strong Thermal Emission Velocity Enhancement (STEVE), this display is crisscrossed by the dusty band of the Milky Way, which curves from top left to bottom right.

A STEVE, captured, in this instance, last year at Childs Lake in Manitoba in Canada, is not an aurora in the traditional sense: Instead of the oval-shaped, blue or green glow of more common types of auroras, a STEVE appears as a thin, purple streak dangling a wavy, green picket fence-like structure. STEVEs always appear at the same time as normal auroras, but they occur at lower latitudes, in an area of the atmosphere called the subauroral zone.

Getting to Know STEVE

In recent years, citizen scientists cataloged dozens of STEVEs and shared them in online

forums. They called the phenomenon “Steve” simply for fun within their own group. In 2016, they shared their collection of Steve photos with the scientists running the Aurorasaurus citizen science project, which tracks auroras through tweets and individual reports. The scientists eventually specially crafted the acronym STEVE to give a nod to the original name and its creators.

New insight into the origin and behavior of this rare atmospheric event became possible when, in 2016, a team of amateur and professional scientists used ground- and space-based cameras to image a STEVE and a simultaneous normal aurora. By combining all of the available images, the team discovered that STEVEs and auroras form from a similar process—charged particles interacting with Earth’s magnetic field—but the particles that create STEVEs travel along magnetic field lines much closer to Earth than those that make up

ordinary auroras. That’s why STEVEs occur at lower latitudes than auroras.

In addition, the scientists were excited to discover that STEVEs are the visual counterpart to subauroral ion drift (SAID), a phenomenon studied since the 1970s. Finding out that SAID can have an accompanying visible feature suggests that there may be more going on in the subauroral zone of the atmosphere than scientists had thought, according to the scientific paper on this discovery, which the team published in *Science Advances* on 14 March (<http://bit.ly/sci-advcs-steve>).

The team is working with NASA on an ongoing campaign to collect more professional and amateur photos of STEVEs, hoping to better understand these rare lights in the sky.

By **Kimberly M. S. Cartier** (@AstroKimCartier), Staff Writer

Oil Spill Response Knowledge Grows, but New Risks Emerge

Oil spills in temperate waters like the 2010 Deepwater Horizon disaster in the Gulf of Mexico are bad enough. But spills in the Arctic would be even worse, according to a well-known oil hazards researcher who spoke this past winter at the annual meeting of the American Association for the Advancement of Science (AAAS). What's more, the risk posed by tankers in the cold, vulnerable north is about to intensify from an expected surge in Russian oil shipments through the Bering Strait starting this summer, said Nancy Kinner.

Strategic partnerships between academia and the federal government are beneficial when spills occur. Kinner codirects one such partnership, the Coastal Response Research Center, a collaboration between the University of New Hampshire (UNH) and the National Oceanic and Atmospheric Administration.

Kinner, a professor of civil and environmental engineering at UNH in Durham, gave a talk at the AAAS meeting about the use of

chemicals to disperse oil released by the Deepwater Horizon rig and other challenges of responding to oil spills (see <http://bit.ly/oil-water-talk>). When that industrial disaster caused millions of gallons of crude oil and gases to gush into the waters of the Gulf of Mexico, responders used a controversial chemical dispersant, applied to the ocean surface and beneath the surface at the oil well, to assist the cleanup process.

Dispersants help break up the oil into smaller clumps, which are easier for ocean bacteria to digest, but they pose their own dangers. Until the Deepwater Horizon incident, the largest U.S. marine oil spill, dispersants were used on only a few spills on a much smaller scale. Now new research on dispersant droplets finds just how small they can get, revealing another danger for spill responders.

After her talk, Kinner, set aside her signature red hat and sat down with *Eos* for a wide-ranging interview. (Her responses below have

been edited for length and clarity.) She discussed with us the current level of oil spill risk—from Russian activities and otherwise, the response options that companies and governments have when spills occur, some new and major findings about the size and danger of dispersant droplets, and her thoughts about oil spills and the future.

There are no cookie-cutter solutions for the problems of preventing and combating oil spills, Kinner said. Instead, she emphasized, “each spill is unique, and every day of that spill is unique.”

Eos: *What is our current risk for marine oil spills? Has that changed from the past, and will it change in the future?*

NK: I would say that our risk of oil spills has gone down to a point. With respect to ocean spills, tanker spills are way down. In a way, we have improved a lot of abilities with respect to drilling in the sea. However, there are some new risks that are emerging.

The Russian petroleum industry, which is owned by the Russian government, is talking about sending tankers of LNG [liquid natural gas] regularly through the Bering Strait, starting this summer. Those are waters that are poorly explored from a navigation standpoint. There are a lot of bad storms, the navigation aids are few and far between, the support



The traditional oil cleanup technique of skimming, in which boats tow booms to corral and capture oil at the sea surface, typically collects as much as 10% of the released oil. Credit: Biloxi Sun Herald/Contributor/Tribune News Service/Getty Images

infrastructure is so poor out there both on the Russian Far East side and even on the U.S. side. We just don't have the infrastructure. I think that's an increased threat.

Then, of course, we have the increased pressure to go further offshore in the Gulf [of Mexico] to get oil. As the price of oil goes up, the attractiveness of that goes up. Though I think we have learned a lot about Deepwater Horizon, we still have very aging infrastructure in the Gulf. The amount of pipeline that's down there is huge. When you have hurricanes, you shut an area, and when you open it up, there can be leaks. It's just old infrastructure.

I'm a little less worried about the current stands by our federal government to expand offshore drilling in areas where it has not been expanded or where it has not been occurring because that takes a very long time to come to reality. We seem not to be weaning ourselves off petroleum, so in the long term that's concerning.

Eos: *What are our current options for responding to an oil spill?*

NK: For offshore spills, dispersants are an option. I think people get that confused. Dispersants are not used until you're at least 3 nautical miles offshore, in water that is at least 10 meters, or 33 feet, deep. The number of times we've used dispersants in this country is very small.

It's really an option for only a very select, small group of spills. You're not going to be doing dispersant application where there are a lot of people. You're not going to be doing dispersant applications subsea where you have very, very shallow water because there is no point in it.

Most of the in situ burns are offshore. You have to have a capability of herding the oil into a relatively thick layer, and it has to have enough material that will burn. It has to be a certain type of oil, or it has to be a certain condition where you can corral the oil. You can't do that with big waves. If it's highly weathered oil, you are not going to be burning it. There again, we have very limited uses of this technology.

The traditional technology is skimming, and it's the preferred technology. The equipment can be deployed and towed through actionable oil. Everybody wants to get the oil out of the water, if at all possible. Unfortunately, you usually don't get more than 10%, and that's a lot. The spill is constantly spreading.

The other thing is that we don't have equipment just sitting everywhere waiting for a very low probability event. One of the things that's being talked about is to have a skimmer that ships could actually carry with them. If there was a spill, it could be deployed. That might work.

But again, when a ship has had an accident like that, people are not thinking about cleaning up the oil. They are focused on human safety. Often times, the deployment of these devices is after we've gotten that very immediate health and safety taken care of.

Eos: *One of the things that impressed me in your talk is how much data and information are coming in to the responders after a spill.*

NK: It's getting worse. I mean it's getting better, but it's getting worse. Imagine having to synthesize all of that information that's coming in from just drones and other things flying over. Those data have to be digested.

Not only do we have gobs of data coming across the Internet, but sometimes, like in Alaska, there aren't places you could send it, because there's no hookup. There are many places where you don't have a hookup during natural disasters.

Storing photographs takes up huge amounts of space. All of this is really challenging, and then all of it has to be digested and translated into something meaningful. People make decisions on meaningful data.

Eos: *What is the timescale for making those decisions?*

NK: Making those decisions is quick. When we talk about models for oil spills, this is always an issue. You need a trajectory model. You need to know now what that trajectory is predicting for 24 hours from now. The model can't take a long time to run. So that's big.

Eos: *Another interesting finding came from the earlier talk by Joseph Katz of Johns Hopkins University. His chamber experiments illustrate the resulting size of oil droplets after encountering a dispersant. You mentioned their size during your talk. Was it surprising to learn the smallest droplets are much smaller than expected, even at the nanoparticle scale?*

NK: It was a huge surprise. He took the first photographs of what happens when an oil droplet encounters a dispersant. He tracked 10,000 droplets. It blew your mind.

I remember going to a meeting and showing that data and saying "Hey, what these health people at Johns Hopkins are saying is that our PPE [personal protection equipment] does not protect our workers." They were horrified. I don't think people could believe that. Those



In response to the 2010 Deepwater Horizon oil spill in the Gulf of Mexico, the largest marine oil spill ever in the United States, airplanes such as this fixed-wing Basler BT-67 released dispersants on the contaminated water's surface. Credit: David Neff/Contributor/Corbis Historical/Getty Images

tiny droplets stay in the air for a long time. There are workers inhaling them into their lungs. Everybody is pretty much accepting it now, but the PPE issue is big. Of course, again, we don't use dispersants on very many spills.

Eos: *If the Deepwater Horizon scenario were to happen in another part of the world, like the Arctic, what are we dealing with then?*

NK: If we had a well blowout in the Arctic, it would be way worse. In that it's dark, it's cold. We don't have resources.

Now we in the U.S. are not right now developing drilling in the Arctic, but as I mentioned the Russians are. And it's going to happen.

We just did a workshop with the Arctic Domain Awareness Center with the University of Alaska. We were imagining what would happen with an oil spill up there, but in this case we were looking at a ship. All of the worst-case things you can imagine, they are there. Oil gets trapped under the ice—is that a good thing? It could be a good thing. It's kind of trapped, but how do you know where it is? What do you do about it?

The Arctic ecosystem is so fragile. It's under such stress out there just from climate change that putting another insult on like that is really a problem.

Eos: *Do you see a day where we don't have to worry about oil spills, or is that never going to happen?*

NK: Not in my lifetime. I think that there will be a lesser and lesser emphasis on using petroleum products. Do I think that they will ever be totally not used? I don't know. I don't see us moving away from ships to move materials. To run a ship on battery, solar, or wind, it's not an easy thing to do. I think there probably will come a day, but I probably will not be around to see it.

By **Laura G. Shields** (email: lgshields@gmail.com; @LauraGShields), Science Communication Program Graduate Student, University of California, Santa Cruz

Former NASA Administrator Weighs In on New Space Agency Head



Charles Bolden, at the Jet Propulsion Laboratory in Pasadena, Calif., smiles as NASA's Mars Curiosity rover begins its descent to the surface of Mars on 5 August 2012. Credit: Brian van der Brug-Pool/Getty Images News/Getty Images

Jim Bridenstine relinquished his duties as a Republican representative from Oklahoma and took the helm as NASA's thirteenth administrator on 23 April. His ascension followed a tough Senate confirmation process that resulted in a razor-thin party-line vote.

Many Democrats have expressed concern that Bridenstine, the first politician to lead the agency, will be too partisan and divisive. Following his swearing-in, however, Bridenstine said that bipartisanship "is important in space." He also said that he is "excited about our science activities that will continue to increase our understanding of Earth and our place in the universe."

What are some of the challenges that the new NASA administrator faces? *Eos* interviewed Charles Bolden, who was NASA administrator from 2009 to 2017 during the Obama administration. The interview, which took place shortly after Bridenstine's 20 April confirmation, has been condensed and lightly edited for flow and grammar.

Eos: What are your thoughts about the new NASA administrator?

Bolden: I'm just glad to see that we finally have an administrator. While he would not

have been my first choice, I think the agency needs political leadership, and I'm just glad that's settled now. I think the agency's good enough to deal with anybody that comes in as an administrator.

Eos: Do you think that he will do a good job?

Bolden: I think he will if he listens to the people and he focuses on getting the mission

"His history is such that he may find some difficulty in working across the aisle."

of the agency done and remains apolitical the way that the NASA administrator has to do.

Eos: Why wouldn't Jim Bridenstine have been your first choice?

Bolden: He would not have been my first choice because he's a politician. And he is the first person, to my knowledge, ever selected from political office to become the NASA administrator.

I don't think it's healthy for the agency to have someone who's a partisan in that position. The position calls for somebody who can carry out the president's agenda to the best of his ability but do it in a nonpartisan way and be able to work across the aisle. And I think his history is such that he may find some difficulty in working across the aisle.

Eos: This was the tightest-ever Senate vote to confirm a NASA administrator. What's the significance of that?

Bolden: It reflects the fact that it is not a consensus selection. So you had all the Democrats opposing, and all the Republicans accepting, and some of the Republicans accepting reluctantly.

Eos: How concerned are you about the agency becoming mixed up in partisan politics?

Bolden: I think anybody has to have some concern, but I'm confident that with the professional abilities of the career civil servants there, along with a significant number of members of Congress who understand what the agency's mission is and really support it strongly, I think it will weather the storm.

Eos: What do you see as Bridenstine's biggest challenges and opportunities as he starts at NASA?

Bolden: Gaining the respect of the workforce. That will be his number one challenge.

NASA has a hugely diverse workforce, not just in race and gender, but in sexual persuasion, in you name it. It's a microcosm of the American populace, and some of its strongest workers and leaders are people who come from communities that he is on the record as not supporting.

Eos: How concerned are you about what some view as the Trump administration's attacks on science and about some of Bridenstine's earlier comments about climate change?

Bolden: What I do is, I look at the budget. People can say a lot of things, but what ends up being the deciding factor is the budget.

And they may be currently looking at ways to go in and modify the budget that was signed and use some budget trickery to not spend funds as directed—every administration tries that. But I think, when I look at the Trump budget, it's a \$20 billion NASA budget, which is incredibly good. It's a lot of money. That's \$2 billion more than I had at any time, and I thought we had some good budgets.

What impressed me was the fact that the Congress ended up putting 400 and some odd million dollars back in the Earth science budget that the Trump administration wanted to take out. I was really concerned about an attack, an all-out attack, on the Earth science budget. I think that comes from the fact that people don't understand what NASA Earth science does. They're not



Jim Bridenstine (left), who on 23 April became the new NASA administrator, at a meeting with the agency's leadership following his swearing-in ceremony. Credit: Randy Showstack

the weather agency, and they don't make any policy, and they don't make rules that people have to follow to help us deal with climate change.

They deliver data. And they do it as well as anybody in the world, as long as they are able to deliver the data. The administration can debate with the Congress and the American people on what the policy should be, but if we take away the ability of NASA to deliver the data, then you have no scientific facts on which to base your decisions.

Eos: *What are your overall hopes for the agency?*

Bolden: My biggest hope is that we remain a beacon for the spacefaring nations of the world.

I hope that we maintain the leadership role that we have today in building an international collaboration of agencies that are seeking to send humans farther out into our solar system than ever before. And I hope that we continue to maintain a balanced focus on the four primary areas: science, human exploration, aeronautics, and technology development. All of that enables us to support STEM [science, technology, engineering, and mathematics] education, sort of one of the unwritten mandates of NASA from the original 1958 space act.

Eos: *What's your advice for the new administrator?*

Bolden: My advice is simple: Take care of your people, and they will take care of you. Do your best to be nonpartisan enough to just put everything that you thought before on the back burner and become dedicated to the mission of the agency.

Don't try to transform it, because it's been around a long time. It may need some tweaks, but it does not need to be remade. That was the only thing I could tell him.

Eos: *When you gave him this advice, did you get a sense that he was listening to you?*

Bolden: I think he was. I've talked to him a couple of times, and I think he was.

Eos: *What's your advice to the science community in working with Bridenstine?*

Bolden: I just ask that they be patient with the administrator and help him understand what it is they do and why it's important. All of us, every single one of us who's come into that job, can be educated and trained. The science community's job is to train us and to make us good administrators so that we help maintain the agency as the great organization that it is.

Eos: *What does NASA mean to this country and to the future?*

Bolden: NASA, in my estimation, is the most powerful soft-power tool that the government has. We interact with more than 120 countries around the world, big and little, powerful and not. And if you look at our relationship with

“My advice is simple.... Do your best to be nonpartisan enough to just put everything that you thought before on the back burner and become dedicated to the mission of the agency.”

Russia today, through Roscosmos, we represent the way that you can work with a potential adversary if you focus on a mission or missions.

So I think that's what it means to the nation. It's an incredible example of what this nation can be if it decides that it wants to exert its soft power and its leadership around the world.

Eos: *And your hope for Bridenstine with that in mind?*

Bolden: I think he sees the critical importance of our international collaborations. I explained to him that he's going to have a difficult time there because that is not what I think his boss—the president—and this administration have that much interest in. So he's going to have to step away from this administration's position, and he's going to have to help the secretary of state explain to people why international engagement is critically important for the United States.

By **Randy Showstack** (@RandyShowstack), Staff Writer



Bolden (foreground) and others react as they watch the Orion spacecraft splash down in the Pacific Ocean after an unmanned test flight on 5 December 2014. Credit: Bill Ingalls/NASA/Getty Images News/Getty Images

Playing Their Way into the Geosciences



Playing often with wooden blocks during childhood is a life experience associated with higher spatial skills as an undergraduate student, a new study found. Credit: FatCamera/E+/Getty Images

Undergraduate students in an average geology class have a wide range of spatial skills, according to a new study that tested the abilities of hundreds of students. The researchers found that the students' scores in tests of those skills correlated with certain life experiences, including types of play as children.

Because women are underrepresented in the geosciences workforce, the researchers paid close attention to gender disparity in spatial skills. They found that one specific life experience removed the difference in test scores between male and female students: having frequently played with construction-based toys. This finding illustrates that spatial reasoning differences between the genders come from experiences rather than from biology, the authors argue in a recently published paper about their work.

"We're trying to see how we can level the playing field to give everyone the same chance and really make sure there are no structural barriers [to] participating in geosciences," said Anne Gold, education and outreach director at the Cooperative Institute for Research in

Environmental Sciences in Boulder, Colo., and lead author of the study.

Gold and her colleagues reported their results in *Geosphere* in February (see <http://bit.ly/geo-sphere>).

Establishing the Baseline

Spatial reasoning is the ability to mentally manipulate visual images, rotating objects in one's mind, for example. Researchers have established that having high spatial ability is a key skill for science, technology, engineering, and mathematics (STEM) disciplines and generally a predictor of success in STEM careers, according to Gold. For example, chemists analyze the three-dimensional shapes of molecules and how they interact physically.

The first step to discovering structural barriers in university-level geoscience education, Gold explained, is determining the range of spatial ability in early undergraduate students. To assess that range, the researchers gave timed tests to 277 undergraduate students enrolled in an introductory geology course at a U.S. university with a student population of

more than 30,000. The tests covered three different spatial skills related to the ways in which parts of an object fit together, including the mental rotation of a three-dimensional structure from one angle to another. Because many students take this course to fulfill their science requirements, the studied group has a broad mixture of STEM and non-STEM majors.

The researchers also collected data on the tested students: demographic information such as gender, academic background such as past coursework and declared major, and play experiences. After students took the tests, they completed a survey in which they reported their childhood play experiences with video games, construction-based toys, and sports. The researchers chose these categories on the basis of past studies connecting them with spatial thinking training. They considered adding other activities to the survey, including craftwork like sewing, but they struggled to develop quantifiable questions around these stereotypically female-gendered skills, explained Gold.

Gender Differences

The resulting test scores varied from 6% to 75% correct. "It's just an enormous range," said Gold. She noted that such a wide range in one of the core skills for STEM fields makes it difficult for instructors to teach and for students to learn. A split between men and women was also obvious in the scores, especially in the mental rotation test.

However, unlike past studies, this new research aimed to determine whether life experiences that may have trained test subjects' spatial reasoning could explain the scores' distribution. Using regression modeling to look at the possible correlations, Gold and her colleagues found that they were able to explain nearly a quarter of the variability in the scores, which Gold noted is significant in the social sciences.

The modeling showed, unsurprisingly, that students who reported having played frequently as children with construction-based toys, such as blocks and connectors, had higher spatial thinking scores. In addition, students who self-reported having played action, construction, or sports video games in childhood scored higher on the tests. A closer look at which traits correlated the most strongly with spatial proficiency showed that it was frequent playing with construction-based toys, not gender, that drove high performance.

The Bigger Picture

The new findings do not conclusively rule out gender as a factor in spatial ability. Julie Libarkin, head of the Geocognition Research

Honoring Earth and Space Scientists

Laboratory at Michigan State University in East Lansing, who edited the submitted manuscript before publication, praised the new study as an example of research others should strive for. However, she said, the findings remain nuanced, and she would like to see the research taken further. “It’s not clear that the difference in spatial skill is the result of playing with construction-based toys or if playing with construction-based toys is the result of having certain spatial skills,” she says. “It’s the chicken or egg question.”

With studies like this one, “we’re getting to a place...in geosciences education research where we can start to ask more fundamental questions that drive at why and how people are successful in STEM fields and in geosciences in particular,” said Eric Riggs, a geology and geophysics professor at Texas A&M University in College Station who was not involved with this spatial skills study.

However, the work also raised additional questions for him. “I’m always interested to see if the same thing holds true in other places around the world or around the country at least,” he said. “Is this just a general human phenomenon, or are we just seeing a small snapshot through a single university?”

Trainable Spatial Skills

Gold acknowledged the limitations in the study and agreed that the general population could display even larger differences in spatial reasoning. She said that testing a more general population could provide more opportunities to increase the pool of future geoscientists.

In the meantime, Gold said she hopes that parents and especially K–12 educators are inspired by these research results. “Maybe [we should be] more strategic than we have been in the past in supporting spatial training at all different levels of our life, starting at play age,” she said.

Undergraduate students with low spatial skills shouldn’t feel discouraged about entering STEM fields. The baseline results are informing Gold and her colleagues on how to design training to increase those skills.

Libarkin agreed, saying that any group of scientists has a range of abilities, and even if one skill level is low, a scientist can learn workarounds. “Anyone can become a geoscientist,” she said.

Jim Green, who served as director of the Planetary Science Division of NASA’s Science Mission Directorate since 2006, stepped into a new role as NASA chief scientist on 1 May. Green was appointed to this position on 10 April by acting NASA administrator Robert Lightfoot Jr. Green has overseen key missions to many solar system destinations and set the groundwork for future NASA missions to Mars and Europa. **Lori Glaze**, who was chief of the Planetary Geology, Geophysics, and Geochemistry Laboratory at Goddard Space Flight Center in Greenbelt, Md., now leads the Planetary Science Division as acting director.

The **Cassini mission team** received the 2018 John L. “Jack” Swigert, Jr., Award for Space Exploration from the Space Foundation on 16 April during the opening ceremony of the 34th Space Symposium in Colorado Springs, Colo. The foundation presents the Swigert award annually for a significant advancement in space exploration during the previous year. The Cassini mission, which ended in September 2017 and was a joint mission of NASA, the European Space Agency, and the Italian Space Agency, was recognized for more than 20 years of work revolutionizing our understanding of Saturn and its rings and moons and how planetary systems form.

Northwestern University announced on 13 April the winners of the 2018 Nemmers Prizes. Among them, receiving the first Nemmers Prize to be awarded in Earth sciences, is **Francis Albarède**, who was recognized for “his fundamental applications of geochemistry to earth sciences.” Albarède is an emeritus professor of geochemistry at École Normale Supérieure de Lyon in France; an adjunct faculty member at Rice University in Houston, Texas; and a world leader in using geochemistry to understand the history of Earth and the solar system. He has contributed to knowledge of high-temperature geodynamic processes, planetary sciences, and marine geochemistry, according to the prize announcement. The honor includes a cash award of \$200,000.

On 5 April, **France Córdova**, director of the National Science Foundation, was inducted into the U.S. News and World Report’s STEM Leadership Hall of Fame. Córdova is an astrophysicist who focused her research on high-energy cosmic phenomena and instrumentation. She is president emerita of Purdue

University; is chancellor emerita of the University of California, Riverside; was NASA’s chief scientist from 1993 to 1996, the youngest person and first woman to hold that position; is a fellow of the American Association for the Advancement of Science and of the Association for Women in Science; is a Kilby laureate and a recipient of the NASA Distinguished Service Medal; was chair of the Smithsonian Institution Board of Regents from 2012 to 2014; and is a past member of the National Science Board.

The NASA Hubble Fellowship Program (NHFP) announced on 3 April its selection of five early-career astronomers as 2018 Sagan Fellows. The Sagan Postdoctoral Fellowship, named in honor of the late Carl Sagan, is one of three prestigious fellowships within NHFP and is awarded to outstanding early-career researchers who focus on extrasolar planets and the origin of life. **Ian Czekala** will research the birth of stars and their young planetary systems at the University of California, Berkeley. **Johan Mazoyer** will investigate the possibility of detecting exo-Earths with large space-based coronagraph instruments at NASA’s Jet Propulsion Laboratory in Pasadena, Calif. **Erik Petigura** will research the origin of small planets at the California Institute of Technology in Pasadena. **Kamber Schwarz** will study the evolution of volatile molecules in protoplanetary disks and exoplanet atmospheres at the University of Arizona in Tucson. **Daniel Tamayo** will research the dynamical evolution of exoplanet systems and how to characterize such systems at Princeton University in Princeton, N.J. The Sagan Fellows will begin their research at their chosen institutions this fall.

Kenneth Graham began his appointment as director of the National Oceanic and Atmospheric Administration (NOAA) National Hurricane Center in Miami, Fla., on 1 April. Graham has worked with NOAA for many years as a leading meteorologist at National Weather Service (NWS) offices around the United States. In his positions within NOAA and NWS, Graham aided Hurricane Katrina recovery efforts in Fort Worth, Texas; advised response teams after the 2010 Deepwater Horizon oil spill; and worked with Mississippi and Louisiana decision makers to predict and mitigate impacts of recent hurricanes along the Gulf Coast. Graham took over the position from **Ed Rappaport**, who returned to his position as the center’s deputy director after serving as acting director since May 2017.

By **Laura G. Shields** (email: lgshields@gmail.com; @LauraGShields), Science Communication Program Graduate Student, University of California, Santa Cruz

Reconstructing Environment and Climate from Coral Archives

Tropical Coral Archives—Reconstructions of Climate and Environment Beyond the Instrumental Record at Society-Relevant Timescales

Bremen, Germany, 28 September 2017



A coral reef in the northern Red Sea has massive *Porites* colonies that are often used in paleoclimate research. Credit: Thomas Felis, MARUM

The tropics are a region of heat gain for the Earth: Tropical ocean sea surface temperatures influence atmospheric circulation, which redistributes heat and moisture from the tropics around the world. Warm-water currents such as the Gulf Stream, Kuroshio, and Agulhas carry excess heat from the tropics to higher latitudes.

Despite their importance, however, the extent of past climate fluctuations in the tropical oceans is still poorly understood. To bridge the knowledge gap, shallow-water corals have emerged as crucial climate archives. The data they provide cover long periods before the start of instrumental observations. The study of these corals is known as coral paleoclimatology.

Last September, 34 experts from Germany, Japan, the United States, Switzerland, Brazil, Indonesia, and Austria gathered for a 1-day workshop at the MARUM-Center for Marine Environmental Sciences (<http://bit.ly/MARUM-center>) as part of the international conference GeoBremen 2017 (<http://bit.ly/GeoBremen-2017>). The scientists, including 11 early-career scientists, represented such various disciplines as geochemistry, paleoclimatology, geochronology, statistics, climate dynamics, and coral ecology. The workshop

was convened to build on the momentum of the successful Future Earth Past Global Changes (PAGES 2k; <http://bit.ly/PAGES-2k>) initiative and to foster a more coordinated approach to coral paleoclimate research.

Tropical corals offer a precise reconstruction of marine climates and environmental change on a monthly timescale. Corals are a key archive for understanding variability over seasons, years, and decades, the timescales most relevant to human societies (Figure 1). Coral reconstructions extending back centuries provide a link between the period of instrumental observations of the past 50–150 years and the coarse geological archives that do not relate to human scales.

These reconstructions are highly relevant when comparing ocean data with model simulations of global and regional climate change. Fossil corals provide snapshots of past seasonality and year-to-year change during glacial–interglacial cycles and across millions of years stretching from the Holocene through the Pliocene and into the Miocene (Figure 2).

Discussions at the workshop focused on identifying key scientific priorities for the coming decades and promoting future joint research activities to understand the long-term impacts of future changes on tropical oceans and reef ecosystems. Participants reviewed the motivations for the new PAGES CoralHydro2k project (<http://bit.ly/Coral-Hydro2k>), temperature estimates from a variety of geochemical proxies and their uncertainties, the challenges with fossil corals, novel proxies for global biogeochemical cycles, and data management and sample exchange.

The workshop emphasized the unique opportunity of coral paleoclimatology to foster collaborations between various disciplines. The group highlighted the added value of measuring paired coral strontium/calcium ratios (Sr/Ca) and oxygen isotope ratios ($\delta^{18}\text{O}$), two key proxies for sea surface temperature that are often referred to as paleothermometers ($\delta^{18}\text{O}$ also reflects sea surface salinity). Pairing these records enables scientists to infer past hydroclimatic variations under changing climatic states like the industrial period, the Little Ice Age, and the Last Interglacial.

Attendees also discussed complicated problems, including hydroclimatic responses to situations in which anomalous events like the 2015–2016 El Niño are superimposed onto long-term heterogeneous ocean-warming patterns. Although these concomitant situations severely affect human societies, at present they are difficult to predict.

Workshop participants made several suggestions on how to further strengthen multinational collaborations, including the following:

- extend a call for participation in PAGES CoralHydro2k to analyze new paired Sr/Ca and

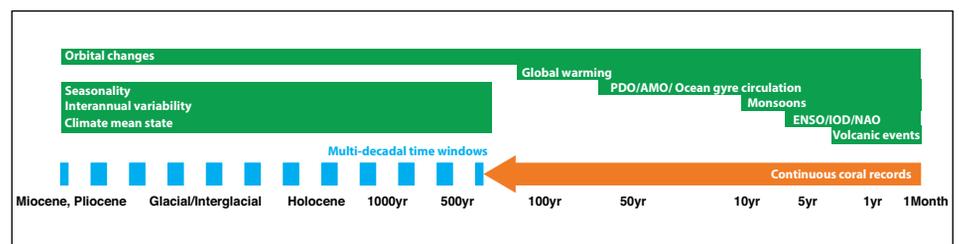


Fig. 1. Time axis illustrating the diverse timescales of climate variability that tropical corals record from various time slices in the past. Abbreviations are PDO, Pacific Decadal Oscillation; AMO, Atlantic Multidecadal Oscillation; ENSO, El Niño–Southern Oscillation; IOD, Indian Ocean Dipole; and NAO, North Atlantic Oscillation.

Winter Conditions Are Changing Rapidly in Alpine Lake Ecosystems

LimnoAlp Workshop

Lake Cadagno, Switzerland, 10–15 September 2017



Fig. 2. Three views of a coral core showing annual density bands: (left to right) ultraviolet image, X-ray image, and visible light photo.

Alpine freshwater ecosystems are affected by multifaceted environmental change, including more frequent extreme weather events, generally warmer winters, and direct human impacts. Changes in winter conditions might be particularly pronounced and affect alpine lakes, for instance, through the timing of ice on and ice off. Such impacts may lead to drastic changes in biotic communities and food webs, with repercussions for key ecosystem processes and services, including the cycling of carbon and dietary nutrients.

Despite their relevance, the ecological consequences of changing winter conditions in alpine lake catchments are still poorly understood. Because of the complexity of these changes and the variety of alpine lake catchments, studying the consequences of changing winter conditions requires a concerted, international research program on a large spatial scale; however, this type of program does not exist at present.

Such a program should apply a standardized methodology in various alpine lake catchments. Chosen catchments should vary in vulnerability to environmental change and comprise a range of human impacts on local and regional scales (e.g., hydrological alterations, fish stocking, atmospheric pollution, and catchment management). They should also differ in natural features, such as geology, lake morphometry, stratification patterns, and biotic community composition.

To pave the way toward such a research program, an international team of freshwater ecologists met for a workshop at Lake Cadagno in the Piora valley of the Swiss Alps. The workshop aimed to identify research questions pertinent to current changes in alpine freshwater ecosystems and their consequences to aquatic communities and ecosystem processes. It also identified nonacademic stakeholders affected by these environmental issues and laid the cornerstones of an international research and training program.

Fifteen scientists, drawn from LimnoAlp (<http://limnoalp.eu>), an existing network of limnologists around the Alps, and ranging from postdocs to professors, engaged in lively discussions around the clock at the local Alpine Biology Center, Lake Cadagno, at the center's

doorstep, provided valuable inspiration for identifying and developing research questions, as did research projects simultaneously carried out by Ph.D. students and postdocs.

Presentations and discussions revealed, among other insights, the following important issues of environmental change in alpine lake catchments due to changing winter conditions:

- **Lake hydrodynamics.** Water stratification within lakes may respond to changes in snow cover and snowmelt as well as to the length of ice cover in winter and heat accumulation during summer. These factors may influence the mixing patterns of lakes and, in turn, ecosystem metabolism and biogeochemical cycles.

- **Aquatic food webs and biodiversity.** These may respond drastically to the loss or establishment of keystone species as a consequence of environmental change, affecting the stability of biotic communities and processes they govern.

- **Ecosystem services, management, and training.** Pronounced changes in ecosystem features may have repercussions for important ecosystem services, including recreation, provision of clean water, and hydroelectricity. Concerted experiments and monitoring in alpine lake catchments along spatial and altitudinal gradients are required to test the generality and dependence of these issues and to train future ecosystem managers and scientists.

Workshop participants identified the European Commission's Innovative Training Network (<http://bit.ly/Innovative-Training>) as the appropriate funding option for a research program to address these issues. If you are interested in this initiative or the LimnoAlp network, please contact any one of the authors. The workshop was supported by the Swiss National Science Foundation.

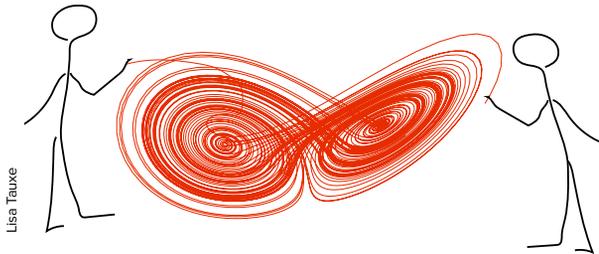
By **Andreas Bruder** (email: andreas.bruder@supsi.ch), Institute of Earth Sciences, University of Applied Sciences and Arts of Southern Switzerland (SUPSI), Canobbio; **Martin Kainz**, Inter-university Center for Aquatic Ecosystem Research Wasser-Cluster Lunz, Lunz am See, Austria; and **Mauro Tonolla**, Laboratory of Applied Microbiology, SUPSI, Bellinzona, Switzerland

$\delta^{18}\text{O}$ records from key locations of the tropical oceans on various timescales;

- begin extended in situ monitoring to capture reef-scale sea surface temperature and improve coral-sea surface temperature calibrations and how these measurements relate to large-scale climate phenomena;
- improve quantitative sea surface temperature estimates from corals (including uncertainties) as a prerequisite for proxy data assimilation with climate models;
- reduce uncertainties of fossil coral reconstructions by replication studies and numerical modeling;
- further develop novel proxies for global biogeochemical cycles;
- convene a joint session at the European Geosciences Union 2018 General Assembly to foster international collaboration (see <http://bit.ly/coral-EGU2018>); and
- convene a PAGES CoralHydro2k side meeting to occur on 1 September 2019 in conjunction with the 13th International Conference on Paleoclimatology (ICP13; see <http://bit.ly/PAGES-ICP13>) in Sydney, Australia.

By **Jens Zinke** (email: jens.zinke@fu-berlin.de; @coralmannie), Institute of Geological Sciences, Freie Universität Berlin, Berlin, Germany; **Miriam Pfeiffer**, Geological Institute, RWTH Aachen University, Aachen, Germany; and **Thomas Felis**, MARUM—Center for Marine Environmental Sciences, University of Bremen, Bremen, Germany

Two-Career Chaos: A Look in the Rearview Mirror



Editor's Note: The following essay, published in Eos on 1 September 1992, describes the difficult personal decisions that faced a dual-career couple as they prepared for a job-related move that uprooted their family and one spouse's career. We are reprinting this piece along with an update from the author on what happened in the ensuing years.

Two-Career Chaos

I was allowed to grow roots. That's what hurt the most. There was a time when everything I owned fit in the back of my car and I could move into a new room in half a day. My posters on the wall, my doodads on my desk and I was home. Now my stuff fills a four bedroom house.

I don't need all my stuff. Sometimes I fantasize about having a huge bonfire and getting rid of it all. But it isn't the stuff that weighs me down, makes me want to stay. Maybe it's my neighbors who are ready with spare eggs and a cup of milk or emergency child watching. Maybe it's my friends who like vines take years to cultivate, nurture, intertwine. Maybe it's my kid's babysitter who loves them as her own. Maybe it's the laboratory I built with my own hands, the research team I've assembled. Maybe it's the thought of the sheer effort of moving. Maybe it's just that I've grown unac-

customed to moving. Something, *something* holds me down and ties me to this place I've grown to love-hate.

When I finished school I suppose I imagined myself as my dad. He worked hard, loved his job and family, made a good living. But I also saw myself as my mom—making a home, raising kids, cooking dinner, saving the world. I can handle being my mom and my dad. I can handle being a scientist and a mother. I can do this.

What I never imagined was the chaotic dynamic of the two-career couple. The motions of

bodies moving in response to the force of gravity cannot be predicted exactly if there are too many bodies. They dance in a jerky jumble, now faster, then slowly, bouncing, jostling, bumping and flying apart. Just so are the career trajectories of the two-career couple. One rises up, the other, slower, pulls it down; overtaking, now supporting, pulling along, now holding back; not moving, leap-frogging, racing in opposite directions and snapping back together with a crack.

The problem is non-linear. The outcome depends on feedback, whether positive or negative. The outcome cannot be predicted, cannot be determined.

Perhaps it cannot be done. Perhaps both husband and wife cannot be both mother and father. Too many mothers, too many fathers. Chaos.

Perhaps it can be done. Perhaps not like our mothers and fathers but a different way. Maybe the jerky path through the mine field of

life keeps us sharp, makes us work harder, leads us through more interesting lives.

My man and I were joined beside a ring of daffodils in a rose garden. My life spread out in all directions, branches and roots, science and family, job and home.

My job is complex. I teach, advise, soothe, stimulate, reassure, guide; I hustle the money, write the papers. I am glue and I am goad. I have tenure. I am a professor. I like my job.

Children sprang from me, arms outstretched to embrace this life. I nursed them, rocked them, came to them when they laughed and cried. I love them, need them. They are mine. They love their dad who laughs loud and long, they love their mom with bedtime song, they love their dad who grows them berries, they love their mom who shows them fairies, they love their dad who builds and cooks, they love their mom who reads them books. How can this whole be broken? It cannot.

Now my husband has taken the perfect job for him, the one he's always wanted. A really good one so I can't ask him to turn it down. He's moving far away where finding a job for me will be hard. What wrenches and aches is this choice that seems so hard but is so clear, so simple—the no-choice between my family and my beloved job. How can I choose to tear our family apart, the children loving both mommies and both daddies, my husband and me. There is no choice here.

So I am pulled up out of my soil by forces far stronger than the poor roots I've grown. I am no longer a tree. I am a seed now. Inside my hard shell is my family, my research, my plans. I can hold out. I will grow again and find my way back to the sunshine.

I'm packing up to go on leave. I'll keep my family whole and work the magic of my research elsewhere for a time. Maybe there will be a change in the weather here. If there is enough room, warmth and nutrients for both of us, we can return. After all, I grew roots.

By **Lisa Tauxe**, University of California, San Diego

Update

What drove us to uproot our family and our lives? The fateful words, "Don't you trust me?"—said by administrators—promising that permanence for my husband was at hand. With those words only in memory, we were left defenseless when he was told, "You must go." And betrayed, we fled.

Our new home, while at the time a fertile garden for one, was cold, hard ground for the other. More words: "You don't need a job; your husband will support you" presaged another choice/no choice. I stayed a seed, with no soil to sprout in.

Happily, the weather we left became more hospitable for my husband with new words: "Come home!" So we returned. The children survived a second uprooting. My husband still mourns the loss of his "perfect" job, off in the land where I could not grow. But now we celebrate together our lives, our family, and our entwined roots.

My advice to couples now: Choose your partner wisely, grow roots together, persist, and, please, get promises from bosses in writing!

By **Lisa Tauxe** (email: ltauxe@ucsd.edu; @ltauxe), Scripps Institution of Oceanography, La Jolla, Calif.

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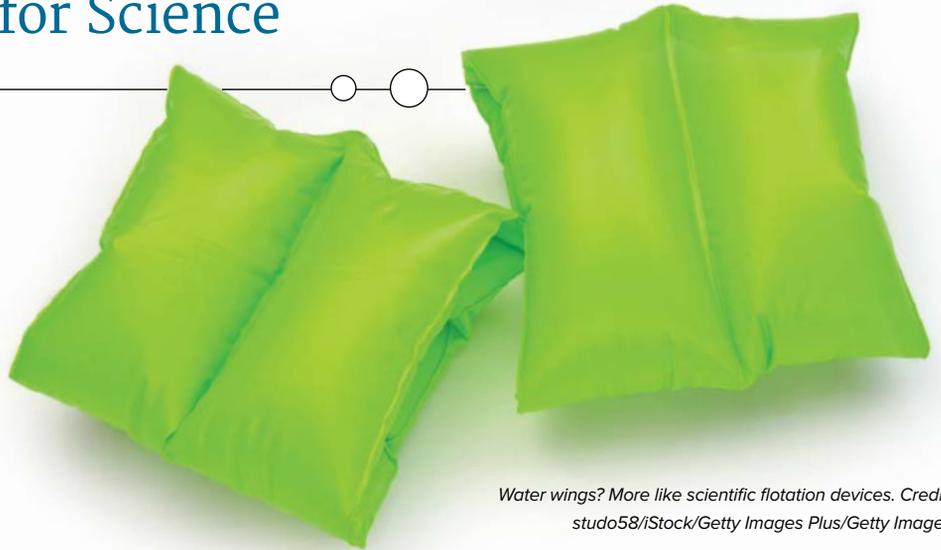
[Mentoring365.org](https://mentoring365.org)

Ten Everyday Objects That Can Be Used for Science

Sometimes when you're designing an experiment or just trying to lug around a bunch of rocks, science makes you think outside the box. Necessity, after all, is the mother of invention.

Like television's Department of External Services agent Angus "Mac" MacGyver, scientists around the world are jury-rigging everyday objects into specialized equipment. And this being the digital age, there's a hashtag for that!

Here are 10 examples of scientists channeling their inner MacGyver with everyday household products, as told by tweets.



Water wings? More like scientific flotation devices. Credit: [studo58/iStock/Getty Images Plus/Getty Images](#)

Mr. Coffee? More Like Mr. Dirt

Jeff Atkins @atkinsjeff

Perfect for grinding up soil for carbon and nitrogen analysis. Gets just the right texture. Will only last about 2 months before it burns up, but easily replaceable at this price. Bonus points for not being as loud as a ball mill. [#reviewforscience](#)



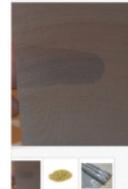
Mr. Coffee Electric Coffee Bean Grinder, Black

Price: \$14.98

Have More Soil to Grind? Try Some Mesh

MH Andrews Holmes @skunkcabbages

Great for grinding soils to a fine powder for analysis. Seller said it's for harvesting trichomes, so it has other lab applications too! Disclaimer: I really thought it meant harvesting trichomes for research & had to be informed otherwise. [#reviewforscience](#) [#straightedgeproblems](#)



10"x10" 80 Mesh / 250 Micron Stainless Steel Kief Screen

Price: US \$9.95

Need to Stay Dry During a Tropical Storm?

Jonathan Kolby @MyFrogCreaks

Replying to @DaniRabaiotti @amazon

The best thing about these trash bags is how well a 5'6" frog scientist can fit inside to stay dry and warm during a tropical storm. Highly recommended for other similar sized field researchers ★★★★★ [#reviewforscience](#)



Master Bag - Individually Folded 50 Gallon Black Polyethylene

Storing Sediment Cores

Rachel Hale @_gitterworm

Freezer bags: These bags are extremely durable. They hold a large sediment core (16cm diam, 10cm deep) easily & do not tear when lobbed across the mudflat towards the shore or when tiredly piled in the van after fieldwork. ★★★★★ [#reviewforscience](#)



Ziploc le handle Food & Freezer bags

OK, So You've Got Your Core. How Do You Clean It?

Andy Emery @AndyDoozerBank

Best implement for clearing years of mould and rime off your sediment cores. 5/5. [#reviewforscience](#)



Wilko Flexible Filza Knife 50mm

It's All About the Festive Colors

Valerie Trouet @vstrout

just the right diameter for storing tree-ring cores in the field. Paper rather than plastic reduces chances of molding. Festive colors make tedious coring job less tedious. [#reviewforscience](#)



Long lasting assorted Colored Paper Pencils 100 Count (Color Random)



AGU Narratives

As part of AGU's Centennial celebration, we're asking Earth and space scientists to share their stories.

NPR's Morning Edition featured Dr. Lora Koenig and Dr. Zoe Courville's story on their friendship formed in the field and how they help each other navigate balancing their work and personal lives.



Listen to their story and learn how to share your own at

centennial.agu.org

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For Those Arctic "Emergencies"

Dani Rabaiotti @DaniRabaiotti [Follow](#)

The great thing about the wide opening on a nalgene is you can urinate in it should the conditions become to extreme to leave your tent. The downside to this is if you drink while hiking or driving off-road water often pours onto your face ★★★ [#reviewforscience](#)

Nalgene Nalgene Plastic Bottles 'Everyday WH' ★★★★★ 70
Amazon's Choice for "nalgene 1L"



Colour Name: [>](#)
Transparent - clear

2:14 am - 30 Jan 2018

And Here Are Some Gloves You Can Wear While "Using" the Bottle

Caia Rottler @CaiaR85 [Follow](#)

Excellent gloves when a surprise April bizzard catches you unprepared while installing PRS soil probes. Also good for insulating cold water bottles, frozen soil cores, and ice packs. Made my hands smell like feet, lack of thumbs did affect handwriting. 4/5 [#reviewforscience](#)



Fit: As expected (91%)

9:11 am - 30 Jan 2018

The Other Kids Won't Make Fun of You, I Swear

Dr. Julia E. East @Julia_E_East [Follow](#)

These floaties come in a handy 2-pack and are great for floating temperature sensors in ponds and wetlands- just attach with fishing line! The major con is that they are not resistant to biting by dogs, after which they sink only to lose your sensor. [#reviewforscience](#)



12:50 pm - 30 Jan 2018

Speaking of Cleaning...

Elizabeth Burakowski @LizBurakowski [Follow](#)

Signstek Telescopic Golf Ball Retriever [#reviewforscience](#). When wrapped with a few generous layers of [#kimwipes](#), this handy device is perfect for cleaning snow off your tower mounted pyranometer: [amazon.com/gp/product/B01 ...](http://amazon.com/gp/product/B01...)



1:05 pm - 30 Jan 2018



PROBING MAGMA RESERVOIRS TO IMPROVE VOLCANO FORECASTS

By Jacob B. Lowenstern, Thomas W. Sisson, and Shaul Hurwitz

When it comes to forecasting eruptions, volcano observatories rely mostly on real-time signals from earthquakes, ground deformation, and gas discharge, combined with probabilistic assessments based on past behavior [Sparks and Cashman, 2017]. There is comparatively less reliance on geophysical and petrological understanding of subsurface magma reservoirs.

So although each year brings exciting advances to the study of magma reservoirs, the link between this research and hazard forecasting, at the moment, is a bit tenuous. Conceptual models of magma reservoirs provide some constraints on hazards but remain highly approximate, as do our ideas about the dynamics of magma mobilization and eruption [Wilson, 2017].

How can we change that? Future improvements in visualizing the subsurface, interpreting signals resulting from magmatic activity, and forecasting eruptions all will require more in situ data and subsurface exploration by

scientific drilling into the very hot, pressurized environment surrounding magmas.

Here, using the Yellowstone plateau in Wyoming as an example, we review the current understanding of magma storage regions as relevant to volcanic hazards. We focus on two popular techniques for characterizing magma reservoirs, one geophysical (seismic tomography) and the other petrological (geospeedometry). We then suggest a third option—scientific drilling—that has the potential to dramatically improve our understanding of magma dynamics.

Magma is a high-temperature mixture of silicate melt, crystals, and bubbles. The relative proportions of these constituents can vary widely, with important implications for eruption potential. Key questions remain: (1) Is magma in the reservoir eruptible, containing more than ~50% melt [Marsh, 1981]? (2) If not, how quickly might the system be transformed from a stagnant, crystal-rich body into an eruptible magma? (3) What ultimately triggers the magma

*Indonesia's Mount Agung spews ash into the sky on 28 November 2017.
Credi: Andri Tambunan/Getty Images*



to erupt? These questions are common targets of present-day geophysical and petrological research.

How Much Melt? Issues with Imaging the Magma

Geophysical techniques such as gravity and electromagnetics have been used to estimate the crystallization state of magmatic intrusions. Most common, however, are tomographic images derived by inversion of travel times from regional or global earthquakes or even from ambient noise.

In our case study of Yellowstone, results from recent seismic tomography studies suggest melt percentages of 5%–15% integrated across the upper crustal magma reservoir that underlies the Yellowstone caldera [Farrell *et al.*, 2014]. Because magma almost never erupts with less than around 50% melt [Marsh, 1981], at first blush it seems unlikely that another eruption could be in the offing.

However, tomography yields an averaged view of the seismic velocity structure in the section of the solid Earth being imaged. It relies on broad seismic wavelengths of hundreds of meters to hundreds of kilometers, thereby limiting the best-case resolution. Even with dense seismometer networks, it is challenging to discern upper crustal anomalies smaller than ~5 cubic kilometers. And the Yellowstone plateau's network isn't this dense. The plateau is very large, so its 40 or so seismic stations are typically spaced at distances of 5–20 kilometers, thus rarely allowing us to resolve features much smaller than 10 kilometers across.

In addition, there are other issues to consider when using tomography. There is no guarantee that the first-arriving waves recorded through the technique transited directly through the magma; they could, instead, have transited more quickly through adjacent colder rocks, thus missing the most liquid rich (slower) regions.

Then there is the complicated issue of translating the modeled velocity delay into an actual melt fraction. The relevant references are analogue lab experiments and theoretical models, but they may not adequately apply to crustal magma bodies. Then add in assumptions on the values assigned for key variables on rock physical properties such as shear modulus and compressibility, which can change with the addition of bubbles, crystals, and directionally dependent factors involving rock texture (i.e., textural anisotropy).

Although the existing tomographic image of Yellowstone is clearly first rate, all of the above confounding factors point to one conclusion: It's still possible that our estimates of melt fractions are inaccurate. There is abundant wiggle room in our best guess at the state of the magma reservoir.

Thus, we have to proceed with caution and accept that our subsurface images remain rudimentary.

Where Is the Melt?

The overall uncertainty affects our assessment of global volcanism. Technological constraints mean that some magma bodies will not be found. Others that we have found will turn out to be fictive.

Eruptible magmas also can hide within an average 85%–95% crystal mush. Back at Yellowstone, Farrell *et al.* [2014] conservatively estimated that 200–600 cubic kilometers of

melt are distributed within a larger crystal mush underlying the plateau. It could be homogeneously distributed, and thus uneruptible, but there are many other options for distribution of melt-rich dikes, sills, or stocks that would yield the average 10% by volume melt fraction observed at Yellowstone.

For example, it seems reasonable to expect that a $5 \times 5 \times 1$ kilometer sill of eruptible magma could reside within the resolution of the existing tomography. That 25 cubic kilometers could produce an explosive eruption larger than any worldwide in the past 200 years.

And what's true for Yellowstone has implications for volcanoes worldwide. The bottom line is that images of crustal magma reservoirs are blurry, uncertainties remain large, and significant volumes of eruptible magma may hide within the imaged crystal-rich reservoirs beneath volcanoes.

Clues in the Crystals

Other evidence for the nature of magma reservoirs is gathered from clues hidden in erupted crystals. The depths and temperatures of magma storage are inferred through what are known as geobarometers and geothermometers. One popular geobarometer is based on the concentrations of volatiles (water, carbon dioxide, sulfur, chlorine, fluorine) dissolved within melt inclusions trapped in erupted crystals: Solubilities scale with pressure, so that higher concentrations imply deeper depths. An experimentally derived geobarometer is based on the aluminum concentration in the mineral hornblende.

Magma temperatures are revealed through the iron and titanium exchange in oxide minerals or similar exchange reactions in feldspars and pyroxenes. Temperatures can also be deduced from the concentrations of titanium in zircon and quartz, an element that increasingly substitutes for silicon and zirconium as temperature rises.

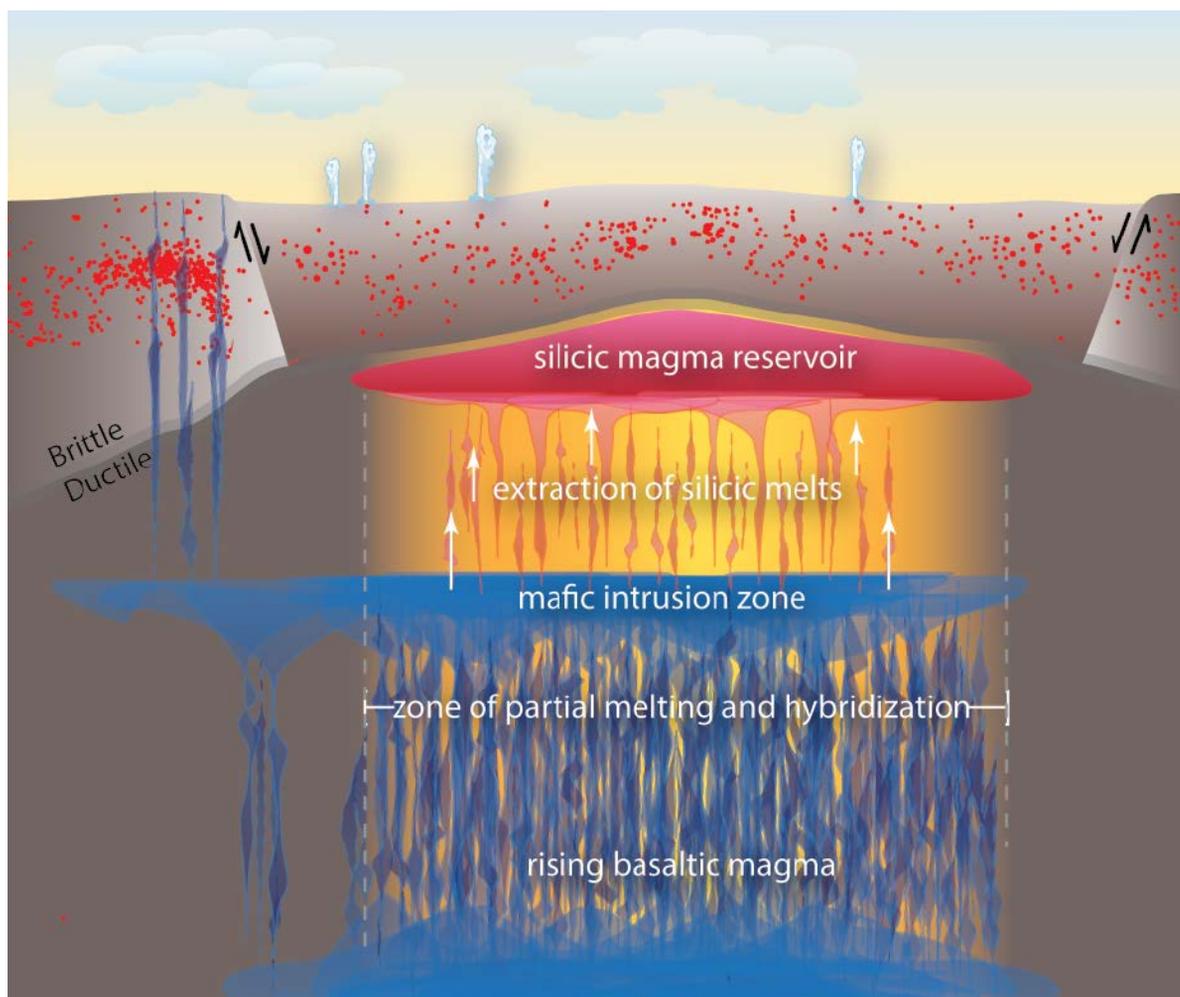
Recently, petrologists have become much better at exploring another key variable: time. Erupted pumices and crystal clots can testify to the processes under way in the subsurface magmatic system.

For example, scientists are exploring how fast silicate melts can be expelled from mostly stagnant crystal mushes. Some recent petrological studies suggest that this process could take as little as a few weeks. They focus on diffusion profiles of trace elements in erupted phenocrysts [Costa *et al.*, 2003].

The concept here is that crystals in the magma reservoir have a late growth episode that creates a sharp compositional gradient. In most cases, the ubiquity of similar rims on similar crystals shows that the crystal growth episode was system wide and therefore reveals a widespread phenomenon, often indicative of a new injection of hot magma that mixes into and disturbs the host magma reservoir.

Over time, any steep compositional gradient in crystal rims would smear out by diffusion at magmatic temperatures. But if the gradient remains sharp, theoretically, that means that the crystal could not have remained hot for very long prior to its eruption.

Using this technique, a study specific to Yellowstone posits that the rhyolite that erupted 250,000 years ago to form the Scaup Lake lava flow was rapidly extracted from a



Schematic of the magmatic system beneath Yellowstone caldera (~50 kilometers in diameter). Tomographic studies estimate 5%–15% melt within the upper silicic magma reservoir. Red dots are earthquake hypocenters. Credit: Modified from Lowenstern and Hurwitz [2008]

crystalline mush that previously lay dormant for 220,000 years. How fast was this extraction? A mere 10 months, the researchers estimate. This quick mobilization was calculated using the time beyond which sharp gradients in trace element concentrations observed in crystal rims would have smoothed out [Till *et al.*, 2015].

But it is important to recognize some uncertainties in these geospeedometers. The crystal rims may have formed within months of the eruption, but how much time elapsed after the system was reawakened and before the last crystal layer was actually precipitated? If the system was heating up to allow loosening of the mush and migration of melt and old crystals, why were the crystals growing, which might be expected to happen instead during cooling? Could that last crystallization episode be years, decades, centuries, or even millennia after the initial perturbation that eventually liberated the future eruptive unit from stagnant mush?

After examining oxygen isotope zoning in coerupted zircons, Till *et al.* [2015] report that this total time period may have lasted up to ~1,200 years. Additional sizable uncertainties remain regarding our experimental calibration of

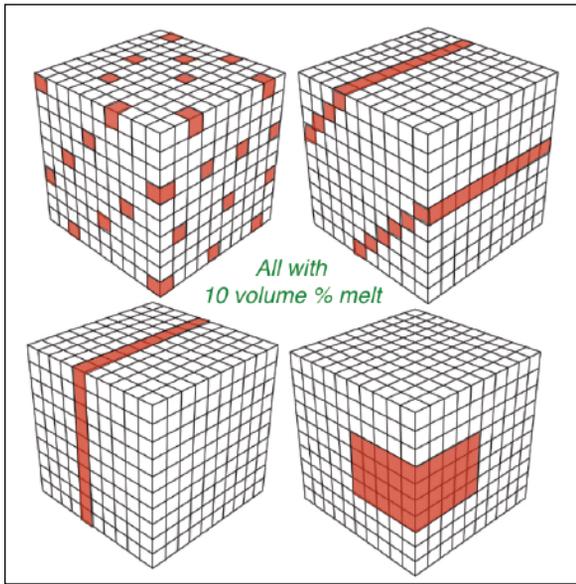
the relevant diffusion coefficients of the trace elements as well as the temperatures at which the elements diffused.

Tying Crystals to Forecasts

It can be hard to know how these crystal-focused studies, although informative, could directly improve forecasting, as is sometimes implied. Clearly, there is evidence for magma mixing in the crystal stratigraphy, but such evidence commonly exists also in interior parts of the crystals, as well as on their rims, indicating that magma recharge does not always trigger a volcanic eruption.

Admittedly, compared with the infrequent eruptions at Yellowstone, many active volcanoes appear to be spurred toward eruptions by deep intrusion of mafic magma [Sparks *et al.*, 1977]. In such systems, we can more readily link crystal stratigraphies to episodes of recent preeruptive unrest, even if we have to wait until the eruption is over to collect the evidence.

Ultimately, such studies will allow us to make progress in understanding how geophysical monitoring ties to magma movement, crystallization, and degassing. Yet even if we can document a mechanism and a detailed history for a

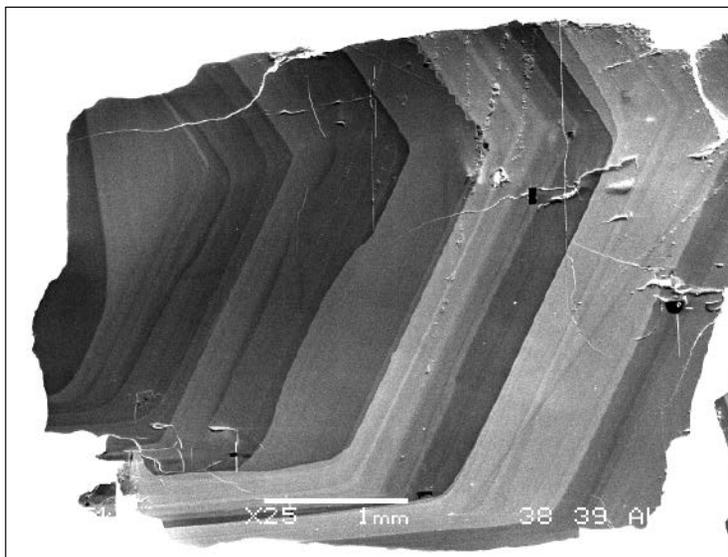


If tomography indicates an averaged 10% magma by volume, it could mean any number of scenarios. The top left schematic shows a more dispersed distribution; in this scenario, an eruption is unlikely. However, the remaining images show (top right and bottom left) dikes and (bottom right) a melt-rich reservoir. In these three scenarios, magma could more readily erupt. Credit: Jacob Lowenstern

given eruption, other mechanisms might be more relevant 10 years later or 100 kilometers away at a different volcano.

Drilling into Magma

All of this points to one inescapable fact. We rarely measure the key variables operating in the magmatic environment. Despite major advances in geophysics and petrology, more in situ data on subsurface magmas and their surrounding hydrothermal shells are required.



Photomicrograph of sanidine from California's Inyo Domes illustrating sharp growth zones. These zones track different episodes in the evolution of the magma surrounding these crystals as they grew. Credit: N. Matthews and J. Vazquez, USGS

We see an underexplored route to get these data: Drill upper crustal magma reservoirs and their peripheries. After drilling, the holes could be used as instrumented observatories.

Among many other possibilities, such data could tell us whether the spectacular inflations and deflations of calderas appear as commensurate and synchronous changes in the temperature, pressure, and flow rates of hydrothermal fluids. Or we might track changes during intrusive episodes by observing real-time seismic velocity changes in the materials in between two drill holes (using one as a source and the other as a receiver).

Drilling studies are expensive, technically challenging, and time-consuming. They require cooling the rock in front of the drill bit to quench a narrow cylinder of melt so that it can be further penetrated.

Ultimately, though, we need to collect and analyze such samples if we want to confirm conceptual models. And we need to collect more data on elusive intensive variables, fluid compositions, and rock properties near and within the magma to model complex monitoring data [Anderson and Segall, 2011; Gregg *et al.*, 2013]. Otherwise, we are basing sophisticated numerical models on rough guesstimates of the relevant controlling variables. Once drilled, boreholes serve as the best observatories we can develop, with a far superior signal-to-noise ratio of geophysical data than is available at the surface.

Past Drilling Campaigns

Past drilling programs near intrusions have yielded critical insights. The work at Kakkonda in Japan revealed the steep permeability and lithological gradients where magmatic and hydrothermal regimes interact at the brittle-ductile transition [Saito *et al.*, 1998].

The Iceland Deep Drilling Program's well at the island's Krafla caldera intercepted rhyolite melt in the region where geophysics had implied it would be absent [Elders *et al.*, 2011].

The very high permeability of the region around the intrusion seems in direct conflict with the lessons from Kakkonda, challenging our existing notions of how temperature, pressure, and permeability should relate.

In the Long Valley Exploratory Well in eastern California, an unexpectedly cool maximum temperature of about 100°C was measured where the presence of shallow magma or at least very hot rock was expected prior to drilling [Sorey *et al.*, 2003].

Perhaps some of the best samples of an actual solidifying magma reservoir were provided by the U.S. Geological Survey's (USGS) drilling into the 1959 lava lake at Kīlauea Iki in Hawaii. The collected core showed temporal change in temperature, growth of crystals, loss of bubbles, settling of olivine phenocrysts, and migration of late-stage liquids as diapirs and into sills, coupled with observations of seismic velocity and electrical conductivity that could be interpreted in light of direct samples [Helz, 1987].

Because we have drilled into relatively few volcanic settings, each new opportunity provides tremendous surprises and new insights.

The Case for Drilling

Many geoscience fields have had great success in incorporating scientific drilling into their baseline data collection. The United States alone has spent more than a billion dollars of public money on ocean drilling [Winterer, 2000]. Private industry has spent many billions of dollars drilling into sedimentary basins, and the result has been continuous refinement of techniques that allow us to reliably interpret a whole suite of geophysical methods (e.g., seismic refraction and reflection).

Unfortunately, the well-studied sedimentary basins and oceanic spreading centers are poor analogues for active continental magmatic systems, which are much more heterogeneous with respect to temperature, pressure, and material properties.

As a result, crustal magma reservoirs remain poorly characterized. We lack the “underground truth” obtained by the detailed drilling programs undertaken in sedimentary basins. But combined geophysical imaging and targeted drilling could greatly improve our images of the volcano subsurface.

Although drilling is seldom allowed in designated wildernesses such as Yellowstone, there are numerous other locations worldwide where suitable volcanic systems can be explored. Safety concerns are magnified in hydrothermal environments, but they can be overcome with adequate planning and prudence.

Volcanic eruptions are some of the most destructive events facing humankind. To prepare for these events, the science of eruption forecasting needs advancement. As we penetrate and monitor the volcano-hydrothermal interface, we will inevitably advance tomographic methods, petrologic insights, and our ability to integrate monitoring data into more robust and reliable eruption forecasts.

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INSTRUMENTATION FOR ENVIRONMENTAL MAGNETISM

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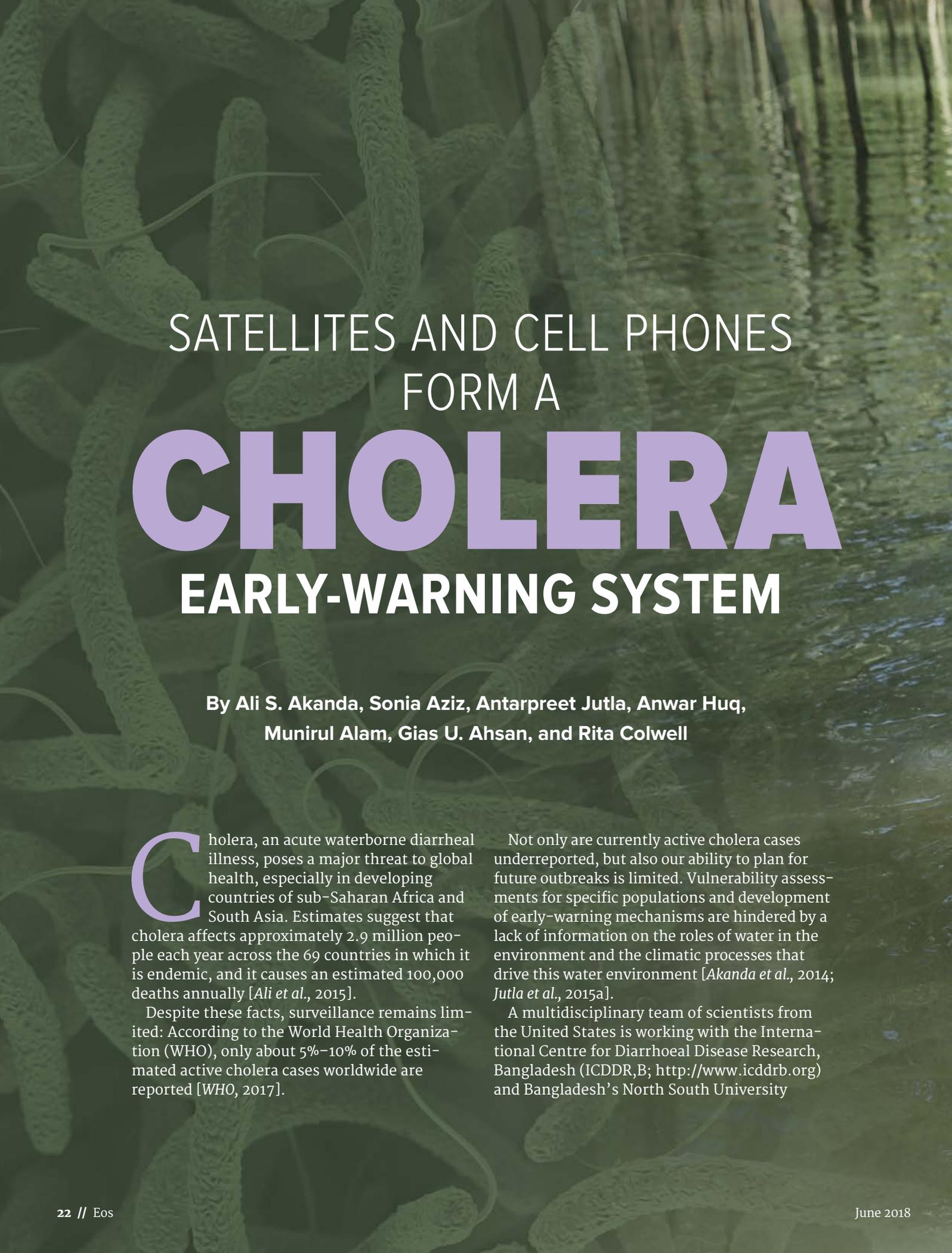
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SATELLITES AND CELL PHONES FORM A **CHOLERA** EARLY-WARNING SYSTEM

By Ali S. Akanda, Sonia Aziz, Antarpreet Jutla, Anwar Huq,
Munirul Alam, Gias U. Ahsan, and Rita Colwell

Cholera, an acute waterborne diarrheal illness, poses a major threat to global health, especially in developing countries of sub-Saharan Africa and South Asia. Estimates suggest that cholera affects approximately 2.9 million people each year across the 69 countries in which it is endemic, and it causes an estimated 100,000 deaths annually [Ali *et al.*, 2015].

Despite these facts, surveillance remains limited: According to the World Health Organization (WHO), only about 5%–10% of the estimated active cholera cases worldwide are reported [WHO, 2017].

Not only are currently active cholera cases underreported, but also our ability to plan for future outbreaks is limited. Vulnerability assessments for specific populations and development of early-warning mechanisms are hindered by a lack of information on the roles of water in the environment and the climatic processes that drive this water environment [Akanda *et al.*, 2014; Jutla *et al.*, 2015a].

A multidisciplinary team of scientists from the United States is working with the International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR,B; <http://www.icddr.org>) and Bangladesh's North South University



A Bangladeshi village woman collects water from a tube well, which taps a shallow unconfined aquifer, amid surroundings flooded with contaminated water. Credit: Mushfiqul Alam/NurPhoto/Getty Images

(<http://www.northsouth.edu>) to address these critical problems of prediction, preparation, and prevention. The team's new initiative combines satellite remote sensing data with ground observations to assess and predict the risk of cholera outbreaks in vulnerable populations of the country.

A Cyclical Problem

In Bangladesh, waterborne diarrheal diseases are the most prevalent illnesses and have a significant impact on public health and the national economy [Daily Star, 2017]. The country suffers from a chronic scarcity of safe water and sanitation access. The monsoonal climate causes drastic environmental changes from season to season. Water sources are highly susceptible to pathogen contamination, including widespread cholera bacteria native to the aquatic environment [Akanda et al., 2013].

In the absence of data, experts have used estimates based on past surveillance and demography to suggest that the effects of large-scale processes (e.g., droughts, floods, coastal storms) put approximately 66 million people in Bangladesh at risk of cholera infection. Approximately 300,000 cases occur there each year, causing an estimated 4,500 deaths [Qadri et al., 2015]. Rapid urbanization has worsened these trends; waterborne diarrheal disease outbreaks occur in informal settlements and villages across the country during both the dry season and monsoon floods [Akanda and Hossain, 2012].

Studies have linked this disease burden to two seasonal transmission cycles driven by regional coastal and terrestrial geophysical processes [Akanda et al., 2013; Jutla et al., 2015b]. Severe water scarcity during the prolonged dry season (November through April) affects water quality in inland freshwater bodies and causes salt water to intrude into coastal areas. Such intrusion brings cholera bacteria, which thrive in this salt water, and exposes a vast population to the risk of infection in southern Bangladesh.

The situation reverses when the monsoon season arrives in June; more than 80% of Bangladesh's annual rainfall occurs in just four months (June through September). The heavy rains destroy safe water sources and sanitation infrastructure, and the flood-induced contamination moves across water networks. Receding floodwaters, rich in nutrients and pathogens, lead to a second wave of outbreaks in postmonsoon months.

Analysis shows that a majority of the vulnerable population is willing to change its preferred water collection methods or sanitation and hygiene habits during these high-risk periods if given advance warning. However, limited information and resource constraints often preclude taking protective action [Aziz et al., 2015].

Forecasting a Cholera Outbreak from Space

To develop forecasts of the risk of a cholera outbreak across Bangladesh, the team monitors regional hydroclimatic processes and changes in the natural aquatic ecosystem with near-real-time Earth observations (EO) obtained from a constellation of NASA satellites (Figure 1). It incorporates precipitation data from the Tropical Rainfall Measuring Mission satellite and its successor, the Global Precipitation Measurement mission (TRMM-GPM); air temperatures from the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument; and water storage information from the Gravity Recovery and Climate Experiment (GRACE) satellites.

These data, along with data from other sensors and hospital and socioeconomic data, are used to assess the hydroclimatological risk of cholera in the study region [Jutla et al., 2015b]. Project findings and results are being used to map unsafe water sources, prepare warnings related to water quality, and predict the potential of natural disasters.

The project findings assist in filling critical information gaps on what, when, and where levels of risks exist and which preventive measures should be taken to deal with problems of unsafe water and sanitation access during critical seasons of the year. To determine the breadth of issues in the environment, the team is implementing a pilot project in two remote locations inside Bangladesh—one coastal and one inland—that represent con-

trasting underlying processes. The ongoing project generates awareness among vulnerable populations and local public health departments.

Willing Residents Need Information

The team conducted surveys on water usage and practices among at-risk households in the coastal Mathbaria area, in the rainfall-heavy inland Chhatak region, and around urban slums in Dhaka. It also interviewed institutional stakeholders (government offices, hospitals, nongovernmental organizations, and others) regarding their understanding of cholera outbreaks, related geophysical processes, and potential uses of an early-warning system.

Interviews with residents and local administration officials in the Mathbaria area revealed that during the dry spring season, a lack of freshwater from upstream rivers and subsequent saltwater intrusion into estuarine areas render most local water sources unsafe to drink. These events also cause contamination with cholera bacteria, which thrive in brackish water.

The surveys found that flooding periodically destroys water infrastructure (e.g., levees and dams) in the Chhatak region. Flooding persists for prolonged periods, even after

Project findings and results are being used to map unsafe water sources, prepare warnings related to water quality, and predict the potential of natural disasters.

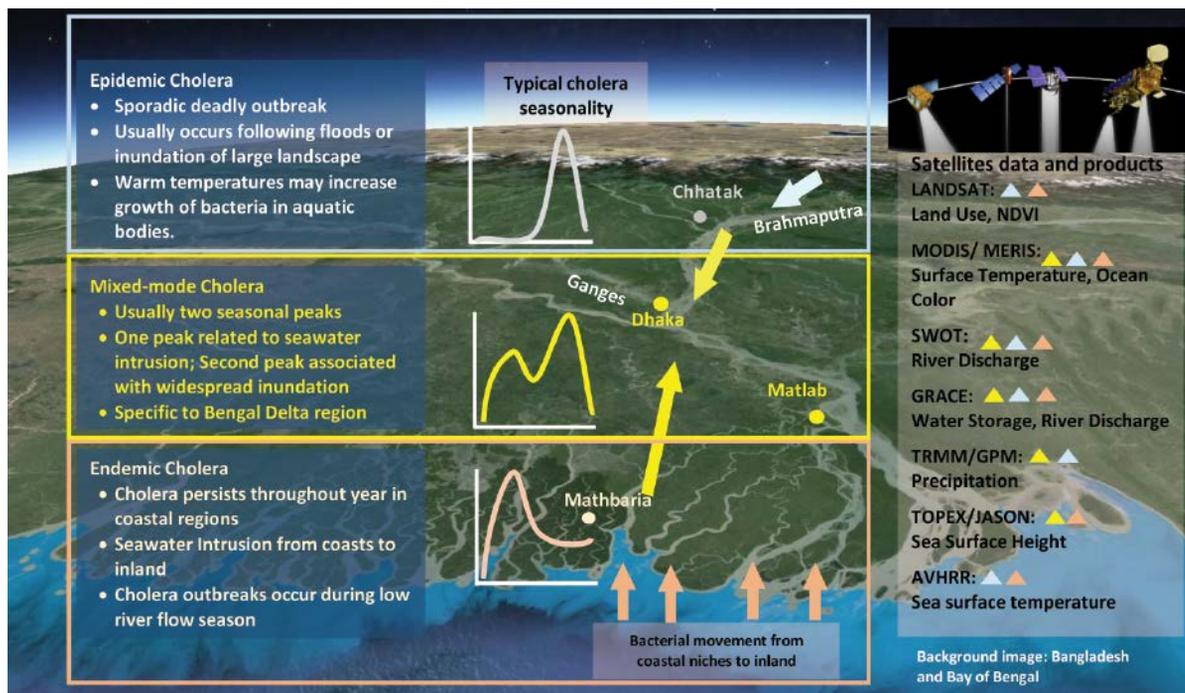


Fig. 1. A constellation of NASA satellites provides Earth observation data for assimilation into a cholera early-warning framework for Bangladesh. Triangles correspond to the type of cholera monitored using each satellite's data. Abbreviations are NDVI, Normalized Difference Vegetation Index; MODIS, Moderate Resolution Imaging Spectroradiometer; MERIS, Medium Resolution Imaging Spectrometer; SWOT, Surface Water and Ocean Topography; GRACE, Gravity Recovery and Climate Experiment; TRMM, Tropical Rainfall Measuring Mission; GPM, Global Precipitation Measurement; TOPEX, Ocean Topography Experiment; JASON, Joint Altimetry Satellite Oceanography Network; and AVHRR, Advanced Very-High-Resolution Radiometer.

a monsoon passes, providing a rich source of nutrients for cholera bacteria and putting a large population at risk of infection. Residents recognized that these outbreaks recur seasonally, but they exhibited a general lack of awareness about the health dangers of unsafe water and the effect of natural disasters on water safety.

Of the families interviewed, 94% indicated that they are willing to change their water procurement and hygiene habits during times of high cholera risk if given advance warning. Water procurers, usually female heads of households, are critical to ensuring that these changes are implemented.

Furthermore, 81% of the sampled population is willing to reveal personal cell phone numbers to receive early-warning messages via an app or text message; this demonstrates a high potential for effective information dissemination. The team found that social media websites, such as Facebook, have very high penetration in rural Bangladesh and urban slums in Dhaka. More than 85% of the people surveyed in urban slums use a smartphone that offers ready access to social media. Special subscription packages from most local cell phone service providers enhance this access still further.

Getting the Word Out

Under the auspices of our project, predictions of high cholera risk periods will be disseminated to agencies responsible for public health, to the overall decision-making hierarchy, and to residents of the vulnerable areas. The

project's partner nongovernmental organizations will advise local water and sanitation regulators and practitioners during periods of heightened risk of cholera. The team will disseminate updates of seasonal and spatial variability of risks and conditions on the ground directly to stakeholder organizations by distributing flyers in the local language (Bengali), conducting awareness workshops, and issuing warnings via cell phones and social media.

The team expects these forecasts to improve the ways in which people in vulnerable locations seek water and their sanitation practices during the critical seasons of the year. As the global health community transitions from Millennium Development Goals to Sustainable Development Goals (see <http://bit.ly/UN-millennium> and <http://bit.ly/UN-sustainable>), similar EO-guided initiatives can play a critical role in meeting water, sanitation, and public health-related development objectives.

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Village women collect water from polluted ponds in coastal Bangladesh. During the dry spring season, salt water flows back from the ocean into coastal estuaries, bringing cholera bacteria with it. Credit: Antarpreet Jutla

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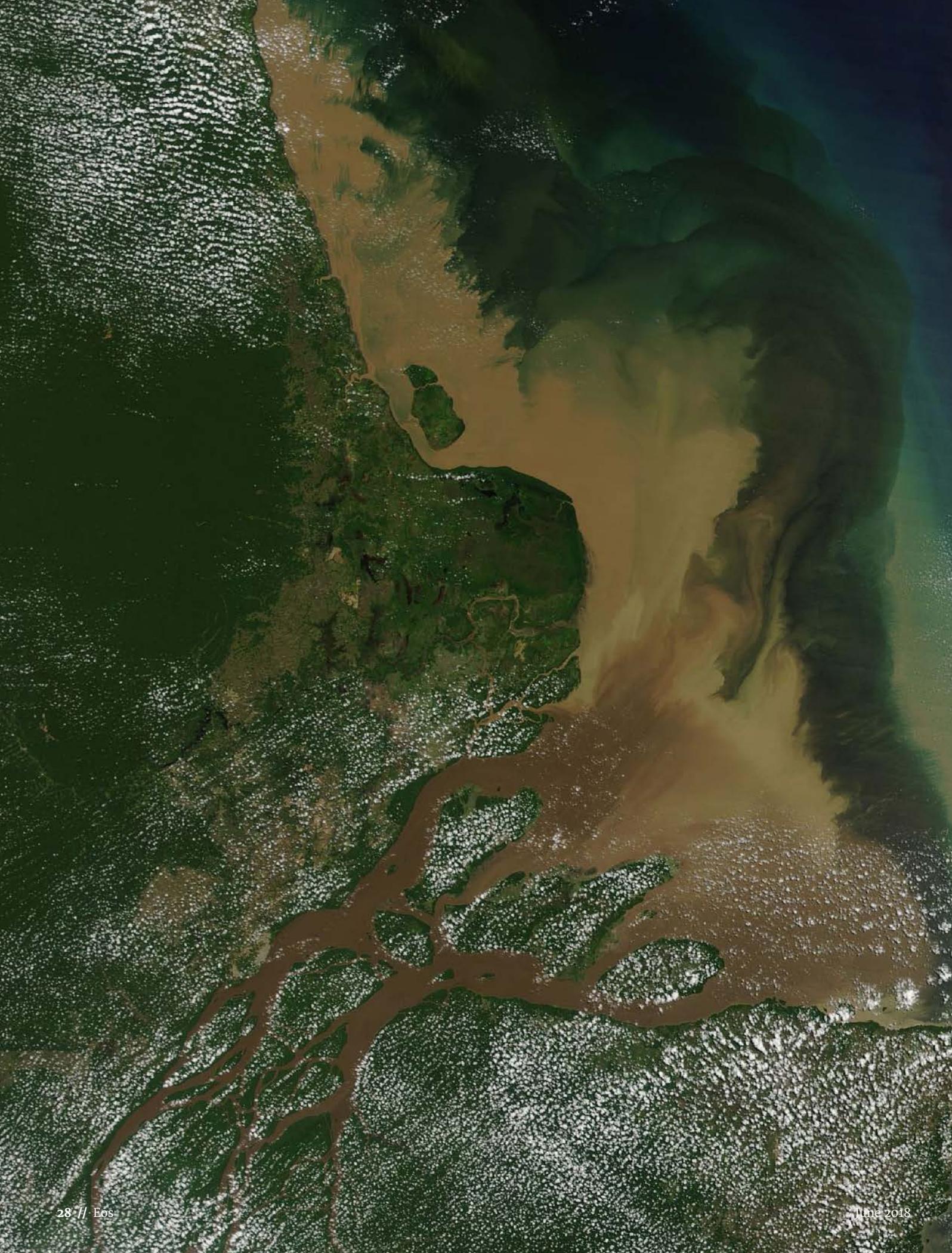


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WHAT
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THE AMAZON RIVER'S ECOSYSTEM WHERE LAND MEETS THE SEA

By Nicholas D. Ward, Henrique O. Sawakuchi,
and Jeffrey E. Richey

The Amazon River basin and the waters of the Atlantic Ocean into which the Amazon flows are home to the world's most diverse ecosystems. This region embodies a rich history of scientific discovery.

During the 1980s, one scientific team discovered that vast amounts of waterborne carbon seemed to simply disappear in transit between the upper and central reaches of the Amazon River and the sea. These researchers, part of the Carbon in the Amazon River Experiment (CAMREX; <http://bit.ly/CAMREX>) project, made early observations of organic matter and suspended sediments flowing through the upper and central reaches of the river. By 2002, researchers discovered that most of the carbon escaped the river as carbon dioxide (CO₂), a phenomenon now recognized as being ubiquitous across inland waters at all latitudes.

What drives these large evasive gas fluxes? How do these processes evolve as the river meets the sea?

From 2010 to 2014, an international team of scientists led by Patricia Yager (University of Georgia) set out to decode the links between microbial and biogeochemical processes occurring along the lower reaches of the Amazon River and its plume, a broad swath just offshore where river water mingles with ocean water. The effort was called the River Ocean Continuum of the Amazon (ROCA) project (see <http://amazoncontinuum.org>).

During the ROCA project, Yager led a series of cruises through the tropical North Atlantic Ocean and into the river plume. Meanwhile, a team of ROCA collaborators led by Jeff Richey (Uni-



versity of Washington) simultaneously probed the lower reaches of the Amazon River, from the Óbidos downstream gauging station to the mouth of the river, where tides completely reverse its flow. The force of the river is so strong that although tides reverse its flow, water can remain fresh a great distance offshore from the river mouth.

ROCA represented the first systematic effort to connect processes occurring in the lower reaches of the river to those occurring in the ocean plume. Previous understanding of the land-sea connection of the Amazon contained a data gap of some 1,000 kilometers between Óbidos and the river mouth, and there were no temporally overlapping studies in the river and the plume.

Our team's most recent project, which began in 2014, aims to further understand biogeochemical dynamics in the lower river. This project is dubbed the Trocas Líquidas de Carbono do Ecossistema do Baixo Rio Amazonas: Da Terra para o Oceano e Atmosfera (Net Ecosystem Exchange of the Lower Amazon River: From Land to the Ocean and Atmosphere, or TROCAS; <http://bit.ly/TROCAS-project>).

Taking the Data

The goal of TROCAS is to develop a holistic understanding of how carbon speciation (e.g., carbon dioxide, carbonate minerals, organic matter) evolves as it travels from the landscape, through river networks to the sea, and, in the case of CO₂, back to the atmosphere. The research framework is based on the concept of net ecosystem exchange, which tracks the evolution of the partial pressure of dissolved CO₂ (pCO₂) on a mass balance basis through defined boundaries of the river system.

We have recently completed the sixth TROCAS expedition (Figure 1). The first four cruises involved performing

The TROCAS team studied what happens to organic matter as it travels along the Amazon River. Shown here is the confluence of (left) the Xingu River, a clear-water tributary, and (right) the main channel of the Amazon River. The team found that when algae-rich waters mix with waters rich in organic matter derived from sediments and the surrounding land, organic matter decomposes at a greater rate [Ward et al., 2016].

measurements while the vessel was under way and doing cross-channel sampling transects along the entire study domain. We started near the river mouth at the city of Macapá and navigated upstream to Óbidos. Then we followed a water mass downstream (an approach called a Lagrangian mode) while also sampling the major clear-water tributaries—the Xingu and Tapajós Rivers—each of which discharges a volume of water on the same order of magnitude as the Mississippi River.

During these expeditions, we performed a suite of experiments to measure how quickly different types of organic matter from terrestrial and aquatic plants were converted to CO₂. We also investigated processes gov-

Previous understanding of the land-sea connection of the Amazon contained a data gap of some 1,000 kilometers.

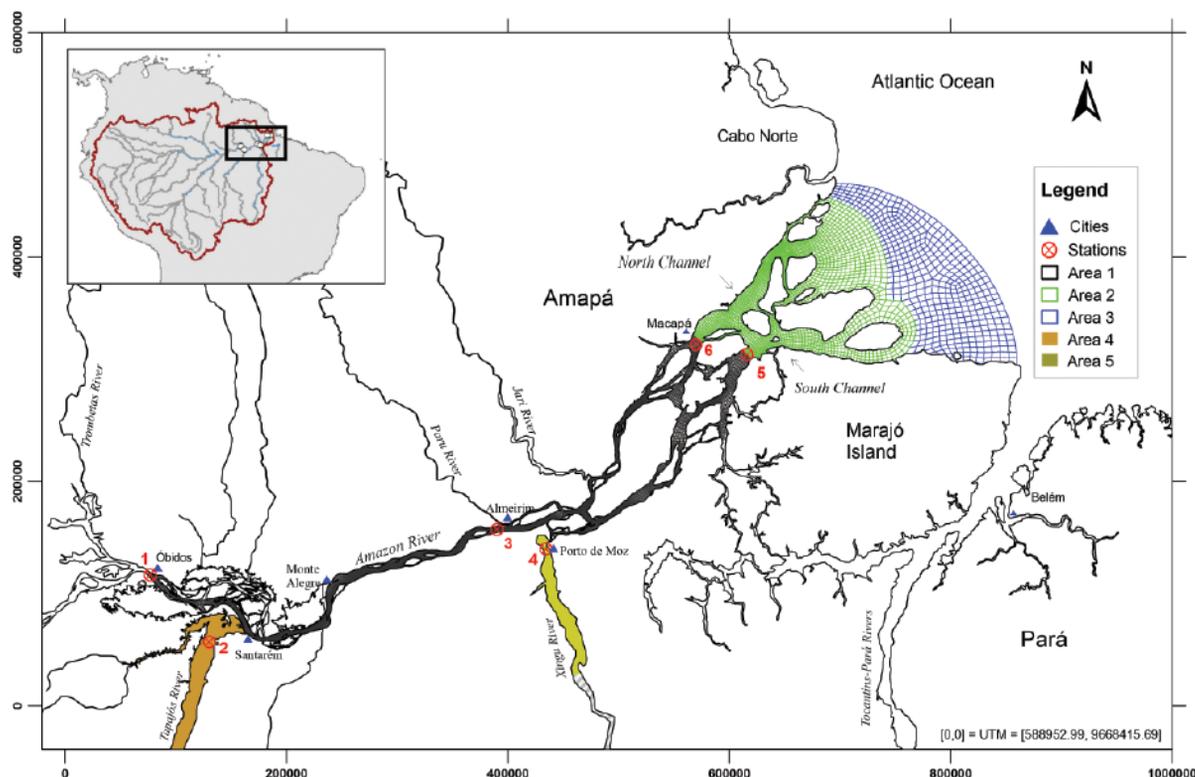


Fig. 1. Our initial study domain for the lower Amazon River extended from Óbidos to the city of Macapá (black), including the Tapajós and Xingu Rivers. In our most recent expeditions, we have traveled to the actual river mouth (green), but waters remain completely fresh up to 60 kilometers offshore (blue). From Sawakuchi et al. [2017].

erning the production, emission, and oxidation of methane in the river, the influence of river hydrodynamics on in situ microbial respiration rates, and the optical signature of organic matter in the river that can be seen from space.

The physical flow of water through this complex and highly dynamic reach of the river is central to all of these questions. We measured river velocity and discharge in situ along the tidally influenced study domain and further compiled these data into a model capable of evaluating biogeochemical transformations (Base System for Environmental Hydrodynamics, SisBaHiA; <http://bit.ly/SisBaHiA>).

Carbon Inputs and Outputs

Data from the ROCA project allowed us to estimate that water took roughly 3–5 days to travel from Óbidos to the river’s mouth. We considered this length of time to be significant relative to the 1–2 weeks it can take for vascular plants to turn over organic matter on the basis of initial incubation experiments.

After adding into the hydrodynamic model the actual river flow across the entire domain, along with bathymetric measurements, we now estimate that complex tidal dynamics extends the water transit time closer to 8–9 days (M. L. Barros et al., unpublished data, 2017). By comparison, more sophisticated incubation experiments showed

that it took anywhere from hours to a day for organic matter derived from leachates of different plants to degrade, with organic matter leached from grasses and aquatic plants decomposing several times faster than that from harder wood tissues [Ward et al., 2016].

Continuous measurements made during discharge surveys and throughout the field campaign revealed an intriguing correlation between the river’s flow speed and the concentration of CO₂ dissolved in the water. This observation motivated us to develop a shipboard system designed to measure microbial respiration rates under various degrees of mixing. Results from these experiments showed a direct link between microbial respiration and physical mixing rates across the lower Amazon River. Respiration rates measured with this system were an order of



The TROCAS team measures gas fluxes and geochemical parameters in the Lago Grande do Curuai during the February 2016 expedition.



R/V Mirage, captained by Valterci “Cica” Almeida de Melo, has traversed the Amazon from the river mouth to Óbidos while making continuous measurements of CO₂, methane, and other geochemical parameters.

magnitude higher than those in past experiments that did not account for river flow, and could almost entirely account for measured rates of CO₂ outgassing [Ward *et al.*, 2018].

From these insights, we have developed the perspective that although land-derived organic matter is rapidly and continuously degraded to CO₂ in the river, constant input from the surrounding land and floodplains maintains high levels of reactive organic matter in the river until these sources are cut off in the inner sectors of the Atlantic Ocean plume.

In fact, measurements in the plume made during the ROCA project revealed observable levels of reactive land-derived organic matter that were degradable during both dark and light incubation experiments. These reactive molecules quickly disappeared as the water became saltier near the ocean, leaving behind relatively stable molecules that persisted throughout the plume.

We conducted experiments with and without light to mimic conditions at various locations in the Amazon River and its plume. The river remains dark below the water’s surface because of its high suspended sediment load, so microbial respiration is the primary pathway for organic matter decomposition upriver. However, as sediments settle in the plume, light can also begin to break down these molecules while also promoting primary production (plants’ conversion of inorganic carbon compounds into organic compounds). The stable molecules that persist throughout the plume might feed the pool of ~5,000-year-

old dissolved organic carbon in the deep ocean [Medeiros *et al.*, 2015].

Where the River Meets the Sea

The full suite of ROCA expeditions and the initial TROCAS expeditions laid the groundwork for interpreting chemical and biological signatures across the river-to-ocean continuum. However, we still had to answer one large question before we could accurately constrain fluxes to the ocean and atmosphere: How do tides influence the distribution and transformation of geochemicals near the river mouth?

Although our initial efforts were highly ambitious, they did not truly connect the river to the sea. The lack was due in part to the logistical difficulties involved in large oceanographic vessels taking samples close to shore and small river boats sampling far offshore. For example, an additional 150 kilometers remain between our river end point, Macapá, and the actual river mouth, and waters remain completely fresh more than 60 kilometers offshore from the mouth.

As such, we spent our final two TROCAS expeditions (November 2016, low water, and April 2017, late rising water) exploring as close to the river mouth as logistically possible in our current research vessel, the *Mirage*, and performing daily time series measurements in fixed locations throughout entire tidal cycles. Measurements made during the final two trips revealed that CO₂ and methane concentrations can vary by an order or orders of magnitude in small, but not insignificant, side channels, and these tidal

effects are seen even in the main stem of the river (the main channel of the river, into which the tributaries flow).

On the most recent voyage, we traveled just beyond the final end point of the geographical river mouth (where water remained entirely fresh throughout the tidal cycle at surface and depth). We are still processing our geochemical measurements, but one striking observation emerged in real time. High levels of $p\text{CO}_2$ persisted all the way to the river mouth, and gas fluxes measured with floating chambers here were similar to rates measured even as far upstream as Óbidos.

When scaled up across the lower river domain, these fluxes are significant not only on a basin scale but also globally. The most recent CO_2 outgassing estimates by Sawakuchi *et al.* [2017] suggest that including the lower reaches of the Amazon River in an updated basin-scale budget increases global outgassing estimates by as much as 40% because of the massive surface area that the lower river encompasses as it widens and channelizes.

These estimates still do not include the extension of freshwater into the ocean, 60 kilometers offshore, where surface area is an order or orders of magnitude greater than for the river itself. Likewise, CO_2 budgets for the plume in the Atlantic Ocean still do not include the inner reaches of the plume and nearshore waters, which likely maintain high levels of CO_2 because of continued breakdown of any remaining reactive organic matter from the river.

Working Together to Find Answers

From our long-term involvement in Amazon research, we recognize that fully constraining the cycling of material through Earth systems requires close collaboration across disciplines and cultures. None of the important discoveries made in the Amazon throughout history would have been possible without the partnership of diverse groups of researchers and, of course, faith from funding agencies.

Our current TROCAS project represents a healthy collaboration among Brazilian and U.S.-based funding agencies, universities, national laboratories, and researchers that

enabled an ambitious field and analytical effort. Through our efforts, we hope to inspire future generations to continue probing the connections between the land, ocean, and atmosphere to develop a holistic understanding of how Earth functions and responds to change.

Some of this work was presented at the 2017 AGU Fall Meeting during the session “Progress in Biogeochemical Research of the World’s Large Rivers II” in a talk titled “The influence of tides on biogeochemical dynamics at the mouth of the Amazon River” (Abstract B54D-02; <http://bit.ly/TROCAS-AGUFM-2017>).

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HOW SUDDEN STRATOSPHERIC WARMINGS AFFECT THE WHOLE ATMOSPHERE

By N. M. Pedatella, J. L. Chau, H. Schmidt, L. P. Goncharenko, C. Stolle, K. Hocke, V. L. Harvey, B. Funke, and T. A. Siddiqui

Weather events 10–50 kilometers above Earth’s surface, in the atmospheric layer called the stratosphere, affect weather on the ground as well as weather hundreds of kilometers above. Experiments demonstrate that resolving stratospheric dynamics enables forecasters to predict surface weather farther into the future, particularly during winter in the Northern Hemisphere [Tripathi *et al.*, 2015]. Thus, meteorologists looking to improve their short- and long-term weather forecasts are seeking accurate models representing the way stratospheric disturbances propagate downward into the troposphere, the atmospheric layer closest to Earth’s surface.

Chief among these disturbances are common events called sudden stratospheric warmings (SSWs). During

SSWs, stratospheric temperatures can fluctuate by more than 50°C over a matter of days.

Recent research has conclusively shown the existence of a strong connection between SSWs and extensive changes throughout Earth’s atmosphere. These changes can affect atmospheric chemistry, temperatures, winds, neutral (nonionized particle) and electron densities, and electric fields (Figure 1), and they extend from the surface to the thermosphere (Figure 2) and across both hemispheres. These changes span regions that scientists had not previously considered to be connected.

Understanding these coupling mechanisms has practical importance: SSWs open the door for improved tropospheric and space weather forecasting capabilities. The implications extend not only to weather forecasting here on the surface but also to greater understanding of chemi-

A view of cloud cover over the Philippine Sea, seen from the International Space Station. The blue envelope of Earth’s atmosphere can be seen on the horizon. Credit: NASA

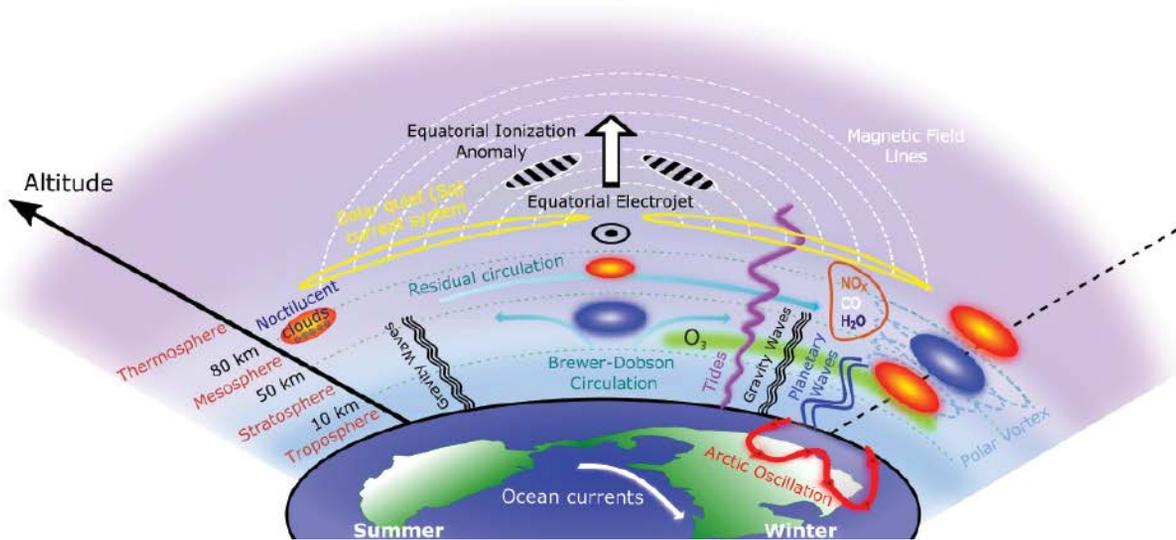


Fig. 1. Schematic of the coupling processes and atmospheric variability that occur during sudden stratospheric warming events. Red and blue circles denote regions of warming and cooling, respectively.

cal processes in the atmosphere, the sources of adverse effects on satellite navigation systems (e.g., GPS) and telecommunications, and possibly even the study of atmospheres on other planets.

How Sudden Stratospheric Warmings Begin

SSWs were first detected in the 1950s, when observations using balloon-borne instruments called radiosondes revealed that temperatures in the Northern Hemisphere wintertime stratosphere go through periods of rapid increase [Scherhag, 1952]. These periods spanned several days and were followed by a decrease toward typical climatological values over the next 1–3 weeks.

Further research showed that despite their name, SSWs actually start in the troposphere. Matsuno [1971] proposed a mechanism for the occurrence of SSWs that is still considered largely valid today: At altitudes of less than 10 kilometers above Earth’s surface, planetary-scale waves form and propagate upward into the stratosphere, where they dissipate. This leads to a weakening of the polar vortex, a confined region of strong eastward winds that forms during wintertime at high latitudes. As the polar vortex weakens, polar stratospheric temperatures increase.

SSW Patterns

The planetary waves that drive the formation of SSWs tend to have larger amplitudes in the Northern Hemisphere compared with the Southern Hemisphere. This is partly because of differences in the distributions of mountains, land, and sea in the hemispheres—tropospheric planetary waves are fed by temperature contrasts between land and ocean as well as by mountains that channel wind flow, factors more prevalent in the north. Thus, SSWs occur primarily in the Northern Hemisphere, although a single strong SSW in the Southern Hemisphere was observed in September 2002.

Although the magnitudes of SSWs can vary, scientists are particularly keen to understand very strong midwinter warmings, referred to as “major” warmings. A variety of

definitions exist, but the criteria for what constitutes a major warming in the Northern Hemisphere often include the reversal from eastward to westward of the longitudinal mean winds at 60°N latitude and about 30 kilometers in altitude.

Major SSWs occur in the Northern Hemisphere winter about six times per decade [Charlton and Polvani, 2007], depending upon the long-term variations in tropospheric and stratospheric winds, such as those driven by the El Niño–Southern Oscillation, quasi-biennial oscillation, and solar activity [Labitzke, 1987].

Surface Effects and Weather Prediction

Hemisphere-scale weather patterns in the wintertime Northern Hemisphere troposphere and stratosphere are associated with

changes in an index called the Northern Annular Mode (NAM) [Thompson and Wallace, 1998]. In the troposphere, the NAM is characterized by a pressure anomaly over the polar region, with an opposite-signed anomaly near 50°–55°N. That is, high-pressure anomalies over the North Pole are coupled with low-pressure anomalies farther south and vice versa. This pattern is related to stronger eastward winds during positive NAM phases (i.e., for a negative polar pres-

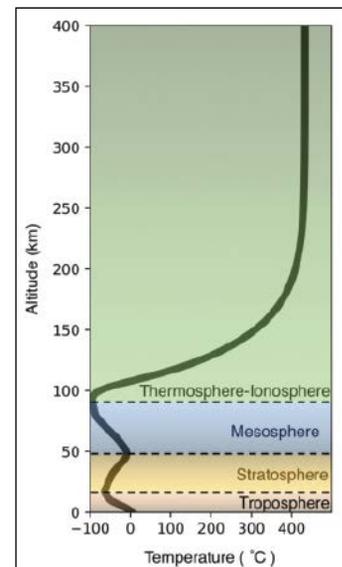


Fig. 2. Vertical profile of atmospheric temperature indicating the different layers of the atmosphere.

sure anomaly) and westward wind anomalies during negative NAM phases. In the stratosphere, the NAM describes the strength of the polar vortex. Negative NAM phases are associated with weak stratospheric polar vortices, like those that occur during SSWs.

NAM anomalies often move downward from the stratosphere to the tropopause (the boundary between the troposphere and the stratosphere) over the course of about 10 days and can then significantly alter extratropical weather patterns during the following 2 months. Knowledge of this downward movement can extend the range of weather forecasts.

Outside the tropics, an SSW can displace extratropical cyclonic storm tracks toward the equator, among other consequences. This displacement increases the probability that storms will pass over the United Kingdom and southern Europe, and it increases the probability of record-breaking cold temperatures and snowfall in eastern North America [Kidston *et al.*, 2015]. Although atmospheric reanalyses and climate model simulations clearly illustrate the downward propagation of the NAM anomalies, we do not yet fully understand the mechanism responsible for the stratospheric control of tropospheric weather patterns.

The downward influence of SSWs extends even to the ocean by providing a persistent forcing to surface winds, which modulate large-scale ocean circulation [Reichler *et al.*, 2012]. However, unlike the relatively short term atmospheric effects, SSWs contribute to variability in the ocean on timescales of 5–10 years. Such variability on longer timescales arises because of the clustering of SSW occurrences, leading to a consistent, multiyear forcing at the ocean surface.

Upward and Outward

Stratospheric wind changes during SSWs kick off a chain of events that lead to anomalies in the stratosphere and up into the next layer, the mesosphere, in both hemispheres. The stratospheric circulation changes during SSWs modulate the spectrum of atmospheric waves that propagate upward into the mesosphere, leading to changes in the daily average wind speeds and temperatures in the upper mesosphere and lower thermosphere (80–120 kilometers above the surface).

The mesospheric wind changes are related to the ways that winds in the stratosphere influence the filtering of atmospheric gravity waves. The mesospheric anomalies often, although not always, initially appear a week or more prior to the peak stratospheric disturbances. This timing gives the appearance that the SSW anomalies propagate downward all the way from the mesosphere to the troposphere, although we do not presently know whether the mesosphere has any control over stratospheric variability.

Warming of the Southern Hemisphere (summer) polar mesosphere also occurs during SSWs. This warming is related to wave-driven circulation changes in the Northern Hemisphere, which lead to a warming of the tropical mesosphere. The altered temperature gradient between the tropics and the southern pole alters the midlatitude summer circulation, changing the filtering of atmospheric gravity waves. With a different gravity wave spectrum reaching the mesosphere, polar summer mesosphere temperatures increase [Körnich and Becker, 2010]. This, in turn,

modulates the formation of polar mesospheric, or noctilucent, clouds [Karlsson *et al.*, 2007].

Much of the high-altitude variability is driven by a phenomenon called atmospheric tides. Like ocean tides, these are periodic, global-scale oscillations in the atmosphere based on the 24-hour day and the effects of the Sun and the Moon on the atmosphere. Changes in stratosphere-mesosphere winds during SSWs lead to a change in atmospheric tides in both the Northern and Southern Hemispheres, demonstrating the global influence of SSWs on the mesosphere.

We also see surprisingly large changes in modes of the gravitationally driven lunar tide. Although generally relatively small, during SSWs the lunar tide meets or even exceeds the amplitude of the normally much larger thermally driven solar atmospheric tides [Pedatella *et al.*, 2014].

Chemistry Effects

Effects from SSWs are not limited to warming and cooling mechanisms. The variability in the stratosphere and mesosphere also modifies the atmospheric chemistry in these regions. This variability includes altering the distribution of atmospheric trace gases, including stratospheric ozone.

In the stratosphere, the descending motion of air within the polar vortex leads to a sharp gradient in trace gas concentrations across the vortex edge. The vortex edge is essentially a barrier between large trace gas concentrations within the vortex and small concentrations outside the vortex, or vice versa. The vortex breakdown during SSWs removes this barrier, increasing the mixing of air between midlatitudes and the polar region. This leads to more homogeneous concentrations throughout the Northern Hemisphere stratosphere during and after SSWs. In addition, SSW-induced temperature changes can modify chemical reaction rates, which is particularly important for upper stratospheric ozone.

Following certain SSW events, the polar stratopause (the boundary between the stratosphere and the mesosphere) re-forms at an altitude of 70–80 kilometers, which is approximately 20 kilometers higher than its usual position. Interaction between the wave forcing and mean winds causes the stratopause and strong wave forcing to descend in altitude. These changes cause chemical species that typically reside in the upper mesosphere to be transported downward into the lower mesosphere and upper stratosphere during the weeks following an SSW. This downward transport results in anomalously large concentrations of, for example, nitrogen oxides (NO_x) and carbon monoxide (CO) in the lower mesosphere and upper stratosphere. The transport of these gases to a lower location in the atmosphere has implications for the chemistry in the polar winter stratosphere, including enhanced levels of NO_x that increase the destruction of ozone.

The Space Weather Connection

Space weather—which describes conditions in the area between the Earth and the Sun—is determined not by the Sun alone, despite popular impressions. SSWs are a considerable source of variability in Earth's thermosphere and ionosphere and are thus an important component of near-Earth space weather.

This is especially true in the equatorial and low-latitude ionosphere, where high ionospheric conductivity in the low-latitude equatorial region causes the most significant SSW-induced variability. SSW events modify large-scale electron density structures within about 20° of the geomagnetic equator in a phenomenon known as the equatorial ionization anomaly [Chau *et al.*, 2012]. The electron density variability during SSWs is of a magnitude similar to that of a moderate geomagnetic storm [Goncharenko *et al.*, 2010], demonstrating that SSWs are a potentially important contributor to adverse space weather.

Tidal changes during SSWs additionally alter the equatorial electrojet, a narrow band of electric current along the geomagnetic equator at an altitude of about 100 kilometers, as well as the global solar quiet current system. Researchers have yet to determine the effect that the variability of the electric field and vertical plasma motion has on the day-to-day occurrence of equatorial postsunset ionosphere irregularities. These irregularities affect communication and navigation signals, so understanding how SSWs induce electric field variability, which would enable us to improve our predictions of these events, is of considerable importance.

SSWs also drive variations in the composition, density, temperature, and winds of the upper thermosphere (about 400 kilometers above Earth's surface). On global scales, satellite drag observations have revealed a reduction in the thermosphere density and temperature during SSWs [Yamazaki *et al.*, 2015]. The roughly 5% reduction in neutral density can have an appreciable impact on satellite drag and orbital debris.

Future Opportunities

The large atmospheric anomalies during SSW episodes allow a better understanding of whole-atmosphere coupling processes. This coupling presents a practical opportunity to improve both atmospheric and space weather forecasting. Detailed knowledge of how stratospheric anomalies influence tropospheric weather will open the door to improved forecasts. The effects of SSWs on the upper atmosphere will enable scientists to improve space weather forecasting, especially for determining the day-to-day variability in the ionosphere.

The physical processes that contribute to the variability of the Earth's atmospheric layers also operate in other planetary atmospheres and define their dynamics and energy budgets. Information gained from the study of coupling between Earth's atmospheric layers is potentially applicable to atmospheres of other planets.

It is unclear what, if any, effect climate change has on the frequency of occurrence and characteristics of SSWs. Moreover, current definitions of SSW events may not be appropriate in a drastically different climate [Butler *et al.*, 2015]. But it is crucial to understand that in a complex and evolving Earth system, any change in SSWs will invariably involve changes throughout the whole atmosphere.

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Virtual Mentoring Rewards Scientists at All Career Stages



The new Mentoring365 program forges mutually beneficial links in the worldwide network of Earth and space scientists between seasoned scientists and those starting their careers. Credit: NicoElNino/Shutterstock.com

Mentoring sessions are among the most valuable experiences that students and early-career professionals can have at scientific meetings. Research has shown that this sort of guidance and attention from a more senior colleague helps prepare mentees for the next steps in their careers. It also increases the retention of women and members of underrepresented minority populations in science, according to a paper published in the December 2007 *Journal of Geoscience Education* (<http://bit.ly/geosci-diversity>) and other studies. Now these one-on-one sessions, filled with sharing of professional knowledge, expertise, and insights through mentor-mentee dialogue, can provide their benefits to those beyond the ranks of meeting attendees.

AGU, in collaboration with the Association for Women Geoscientists, the American Meteorological Society, Incorporated Research Institutions for Seismology, and the Society of Exploration Geophysicists, has launched a virtual mentoring program called Mentoring365 (<http://bit.ly/Mentor-365>). This entirely virtual program offers mentees the valuable opportunity to connect with professionals from a variety of industries and backgrounds located across the world who may be otherwise inaccessible.

Guided Program of 3-Month Mentorships

Mentees have the opportunity to select a mentor from dozens of professional profiles that make it possible to identify a potential mentor with a similar area of study and interests. Once a mentor is selected, the pair takes part in a 3-month program that allows participants to set their own weekly meeting time and to begin their interactions at any time of the year.

During that period, Mentoring365 sends weekly emails that include links to resources and tips about various topics to the mentor and mentee to assist with their discussions and guide them through the program. The content of the emails helps to establish and promote work toward the mentee's goals by means of recommended discussion topics and resources. The program calls for just 30 minutes per week set aside to have meaningful conversations. By the end of the program, mentees and mentors typically have made a valuable connection.

One of our mentees, Maud, an undergraduate student participating from Ghana, commented, "I am very happy to be part of the mentoring program, and I have learned so much from my mentor. I have so much zeal now towards my graduate school application...all thanks to my mentor and this

initiative. Having served as a good protégé and [been] honored with a good mentor like mine, I hope to mentor students like me sometime in the future and aid them in their career objectives. Thank you for this great opportunity given me to be part of this wonderful platform."

For experienced professionals, Mentoring365 provides a simple platform to use to impart wisdom and support a new generation of Earth and space scientists. As explained by research scientist and Mentoring365 mentor Hazel Bain of the Space Weather Prediction Center of the National Oceanic and Atmospheric Administration, those times when "I have thrived in my career coincide with the times [when] I have had a good mentor to advise, support, and cheer on my behalf. I certainly don't have the answer to every problem, but I'd like to be able to share what I have learned and the experiences I've had along the way, in the hope that [those] might help others."

A Way to Give Back

Mentoring365 provides a simple avenue for scientists who are interested in giving back after having had the benefit of mentors themselves. Mentoring365 mentors range in career stage from postdoctoral researchers to senior scientists. A successful mentor dedicates 30 minutes to an hour each week to prepare for weekly meetings and is passionate about providing guidance and sharing knowledge and experiences with the mentee.

Since the program's launch in September 2017, Mentoring365 has recruited approximately 300 mentors and mentees from 52 countries on six continents. Since then, the growing program also has seen the addition of two new partner organizations that have helped to increase the scope of our mentors' backgrounds and fields of study.

Although the program has reached these milestones, only a third of participants have found a successful match, mostly because of a limited number of mentors. Earth and space science professionals are encouraged to apply as mentors (see <http://bit.ly/mentr-app>), and we invite potential mentees to apply (see <http://bit.ly/Mentee-app>) and expand their global network today! With a growing mentor pool, we hope to meet the diversity of needs so that more successful Mentoring365 matches can be made.

By **Kaylin Schupp** (email: mentoring@agu.org), Winter 2018 Talent Pool Intern, AGU; **Maggie Irwin**, Fall 2017 Talent Pool Intern, AGU; **Leslie Marasco**, Student Programs Coordinator, AGU; and **Pranoti M. Asher**, Higher Education Manager, AGU

An Improved Understanding of How Rift Margins Evolve



An extensional detachment fault in western Norway. In a new study, researchers examine how crustal-scale extensional faults successively link and interact to produce the architecture of a rifted margin. Credit: Per Terje Osmundsen

Earth's surface is continuously reconfigured by the assembly and breakup of supercontinents. As part of this cycle, landmasses split apart at continental rifts, linear zones where the lithosphere is stretched and lowered and new oceanic crust forms.

Geologists have long understood that rifted margins are characterized by several types of normal faults that accommodate this extension, including steep faults with up to a few kilometers of vertical displacement and lower-angle faults that can accommodate tens of kilometers of horizontal motion. Although the growth of these steeper faults has been systematically studied in rift margins, the role that the lower-angle faults play in these settings is not as well understood.

To bridge this gap, *Osmundsen and Péron-Pinvidic* studied the range of faults present along the mid-Norwegian margin, an important oil- and natural-gas-producing area that experienced multiple episodes of rifting between the late Paleozoic and early Cenozoic. Using several sources of seismic reflection data collected in the Norwegian

Sea between 1984 and 2008, the researchers identified five structural domains that formed via the linkage of large extensional faults.

The faults combined into what the authors call “breakaway complexes,” which distinguish the margin’s proximal and necking domains, with thicker continental crust and higher-angle faults, from its distal and outermost portions, which are recognized by their increasingly isolated slivers of crystalline continental crust and the presence of lower-angle faults. Seaward of the outermost breakaway complex, nearly flat detachment faults prevail. The 3-D architecture of the rifted margin develops mainly through the lateral and downdip interaction between these faults.

By defining these structural domains in a novel way, this study places low-angle, high-displacement faults within a broader framework. This perspective will help researchers better understand the lateral variability of rift-forming processes and, ultimately, how these margins—and their economically important sedimentary deposits—evolve. (*Tectonics*, <https://doi.org/10.1002/2017TC004792>, 2018) —Terri Cook, Freelance Writer

Visualizing One of the Most Hazardous Formations in Nature

Southern Italy—between the ankle and the calf of Italy’s geographical “boot”—is home to one of the most dangerous places on Earth: the Campi Flegrei caldera. A caldera is a vast depression in Earth’s surface created by magma vacating an underground reservoir during an eruption. Regions containing calderas are often volatile, and Campi Flegrei is especially hazardous because of its proximity to the city of Naples. An eruption (which researchers estimate could happen in the next 500 years or so) would be disastrous for the more than 1.5 million people who live there.

The on-land portion of Campi Flegrei has been studied extensively since ancient Roman times, and the area is currently monitored by a network of 14 seismic stations; 17 continuous GPS stations; and 9 tiltmeters, which measure slight changes in slope across a surface. The part of the caldera that is submerged under the Gulf of Pozzuoli—roughly half its total area—has been studied to a lesser extent, but scientists have been collecting marine data since 2008 through the Cabled Underwater Multidisciplinary Acquisition System (CUMAS) platform. CUMAS uses a suite of instruments on board a buoy and on the seafloor to detect seismic activity, hydroacoustic waves, water pressure, and displacement of the seafloor. In 2016, three more buoys containing even more instruments were added to CUMAS to form the Multiparametric Elastic-beacon Devices and Underwater Sensors Acquisition (MEDUSA) system.

Iannaccone et al. used data collected by MEDUSA to generate the first image of seafloor deformation patterns in the Gulf of Pozzuoli portion of the Campi Flegrei caldera. The team found that from April to June 2016, some sections of the seafloor were uplifted by approximately 4.2 centimeters.

The researchers also compared these GPS seafloor data, transmitted from MEDUSA’s four buoys to the Osservatorio Vesuviano monitoring center in Naples, with values projected by a model using only GPS land



The Campi Flegrei caldera as seen from NASA’s Earth Observing-1 satellite in 2012. Credit: NASA

measurements. Their results matched up, showing that either data collected on land or data from the seafloor can be used to determine the other. They also found that bottom pressure records, or measurements of pressure at the bottom of the ocean, could be used to determine seafloor uplift in shallow water.

Not only did the team provide the first image of seafloor deformation patterns beneath Campi Flegrei, a critical caldera, but also their study is a good example of how GPS buoys can be used to monitor submerged volcanic regions in general. It also shows the potential for using bottom pressure records as a cost-effective, high-resolution mode of monitoring shallow waters. (*Journal of Geophysical Research: Solid Earth*, <https://doi.org/10.1002/2017JB014852>, 2018) —Sarah Witman, Freelance Writer

Prairies, Potholes, and Public Policy

The Prairie Pothole Region of North America—a vast expanse of grasslands, or prairies, interspersed with shallow wetlands, or potholes—stretches across Iowa, Minnesota, and the Dakotas in the United States and north through Saskatchewan and Alberta in Canada. These wetland formations, left behind by receding glaciers thousands of years ago, are home to many animal species, including more than half of all migratory waterfowl in North America, and play a key role in controlling flooding by absorbing rain surges, snow-melt, and floodwaters.

The study of how wetlands interact with one another and with other water systems is a thriving area of research, especially because it helps inform public policy. For example, the federal Clean Water Act is intended to protect the integrity of “navigable waters”; Clean Water Act regulatory protections have often been interpreted to apply specifically to those wetlands that may affect traditional navigable waters.

To better understand the relationship between wetlands and water flowing into streams, *Brooks et al.* zeroed in on the Pipestem Creek watershed in North Dakota. The team collected water samples over a 2-year period (2014–2015) in prairie pothole wetlands and a nearby

stream and compared them with data detected by NASA’s Landsat satellite over the same time period.

Chemical signatures left behind by hydrogen and oxygen isotopes during the evaporation process (called isotopic evaporation signals) allowed the researchers to trace back the water’s path. From this, they were able to estimate how much the wetlands collectively contribute to the stream’s flow, as well as how large the water’s surface area would need to be to generate such a signal. Their findings indicated that the wetlands near Pipestem Creek contribute to the stream’s flow throughout the summer and that sections of the stream occasionally become disconnected.

This study demonstrates an innovative new approach to estimating wetlands’ impact on surrounding aquatic systems and tracing the pathways of surface-level water and groundwater. By combining isotopic measurements of water samples collected in the field with satellite data and perhaps incorporating additional types of data, scientists can continue to build a richer understanding of wetland water systems—and perhaps help improve the management of these ecosystems. (*Water Resources Research*, <https://doi.org/10.1002/2017WR021016>, 2018) —Sarah Witman, Freelance Writer

Widespread Mantle Upwelling Beneath Oceanic Transform Faults

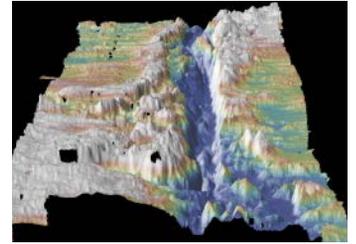
New oceanic crust is forged along Earth's mid-ocean ridge system, a global chain of volcanic spreading centers whose segments are offset by perpendicular transform faults. Because these faults are not present during continental rifting, the first stage in the formation of a new ocean basin, but are pervasive features of newly minted seafloor, it remains unclear when they form and how their presence is perpetuated.

Seismic anisotropy, the directional variation in the velocity of seismic waves, is influenced by individual crystal alignment and is therefore a potentially powerful tool for deducing patterns of mantle flow along divergent plate boundaries. To date, however, the difficulties and expense of instrumenting the seafloor have limited the application of this technique. Now *Eakin et al.* have refined a method for conducting such measurements along mid-ocean ridges and have used the results to elucidate the role of transform faults in seafloor spreading.

By carefully eliminating seismic stations in areas where the underlying mantle displays directionality, the team was able to measure the mantle properties beneath individual earthquake sources, rather than below each station, as is typical for this method. For the first time, this modification allowed the researchers to characterize mantle flow beneath active transform faults on a global scale.

The observed patterns of nearly vertically aligned anisotropy suggest that widespread upwelling of the mantle is occurring beneath oceanic transform faults. These results, which are consistent with geodynamic models, imply that mantle upwelling warms, and consequently weakens, transforms. These features thus appear to play an important role in localizing strain and ultimately helping to stabilize divergent plate boundaries.

In addition to representing a significant advance in how measurements of mantle anisotropy are conducted, this study is noteworthy for predicting the dominant pattern of mantle flow beneath transform faults. As more ocean bottom studies are conducted along mid-ocean ridge systems, these results offer a working hypothesis for other researchers to test. (*Journal of Geophysical Research: Solid Earth*, <https://doi.org/10.1002/2017JB015176>, 2018) —**Terri Cook, Freelance Writer**



Seafloor bathymetry of the Chain transform fault on the Mid-Atlantic Ridge from the Passive Imaging of the Lithosphere–Asthenosphere Boundary (PILAB) experiment. Credit: Nick Harmon and Catherine Rychert

Sea Ice Loss Suppresses Some Effects of Climate Change

Sea ice in the Arctic goes through seasonal changes each year, receding to its minimum extent each September and then refreezing to its maximum over the winter. In recent decades, however, sea ice minimums have been getting smaller and smaller. The Arctic currently is warming at twice the rate of the rest of the world—part of a phenomenon called polar amplification—and its ice is declining by more than 10% per decade. All 10 of the lowest sea ice minimums on record have occurred since 2007.

Numerous studies have shown that as carbon dioxide emissions amplify the impact of the Sun's radiation and sea surface tempera-



Scientists exploring Arctic sea ice in 2005. Credit: Jeremy Potter/NOAA

tures warm, weather patterns shift from the tropics toward the poles. *Zappa et al.* examined how sea ice loss and polar amplification could potentially counteract these shifts.

Using the Coupled Model Intercomparison Project Phase 5 (CMIP5), the team analyzed climate simulations from 37 different models. It identified the behavior of atmospheric circulation in response to increasing carbon dioxide and sea surface warming and then compared the results with a projected scenario over a future 30-year period (2069–2099), which also includes reductions in sea ice cover.

The results of multiple models showed that sea ice loss would have an impact on atmospheric circulation in the midlatitudes (the area between the tropics and the poles) between January and March, which is when surface temperature changes related to sea ice are greatest. The researchers also found that sea ice loss would suppress the poleward shift of the North Atlantic jet stream due to climate change in late winter. It would also increase surface pressure (the weight of the atmosphere pushing down on the Earth's surface) in northern Siberia and lower it in North America, which would have implications for regional climate.

This study is the first successful attempt to use a suite of multiple models to show the impact of sea ice loss on atmospheric circulation. With recent reports estimating that the Arctic could be entirely ice free by 2040, scientists have every motivation to learn all they can about this sensitive region. (*Geophysical Research Letters*, <https://doi.org/10.1002/2017GL076096>, 2018) —**Sarah Witman, Freelance Writer**

A Quantitative Look at the United Nations' Global Vision for 2030



Seychelles national parks researchers map coral reefs around Mahé Island. In 2015, the United Nations set 17 goals to improve the lives of people in all countries by 2030, including goals for protecting oceans and underwater habitats like these. Credit: UN Women/Ryan Brown, CC BY-ND 2.0 (<http://bit.ly/ccbynd2-0>)

In 2015, the United Nations launched a series of 17 so-called Sustainable Development Goals (SDG) to be pursued in all countries by 2030. The goals include ending poverty, eliminating hunger, promoting good health and well-being, high-quality education, gender equality, clean water and sanitation, affordable and clean energy, decent work and economic growth, innovation in industry and infrastructure, reduced inequalities, sustainable cities and communities, responsible consumption and production, taking action on climate, protecting life underwater, protecting life on land, peace and justice bolstered by strong institutions, and partnerships toward achieving these goals.

Within the 17 goals are 169 targets and 230 indicators designed to measure countries' progress toward each goal. There has been a lack of comprehensive and quantitative research in this arena, however, especially in terms of how progress toward one goal affects another. In a new publication, Pradhan *et al.* seek to rectify this shortcoming.

The researchers compared indicators from the list in sets of two, using the official SDG data to help determine whether each pair had a positive correlation (a synergy) or a negative correlation (a trade-

off). Synergies and trade-offs within and between goals were represented by percentages of the positive and negative correlations. The team then ranked synergies and trade-offs at both global and national levels to identify the most common SDG interactions.

The researchers found that for any of the 17 goals, there were more potential synergies than potential trade-offs; in other words, there were more positive than negative correlations. They were also able to trace more specific global patterns; for example, they found that the “no poverty” goal (SDG 1) has a synergistic relationship with most of the other goals, whereas “responsible consumption and production” (SDG 12) presented a trade-off scenario in most cases. The researchers recommend leveraging the synergies that they identified, as well as negotiating and strategizing further, to try to overcome the trade-offs.

As outlined, the Sustainable Development Goals have the potential to protect the environment and improve the lives of billions of people. This study shows, in greater quantitative detail, what it might take to actually achieve them. (*Earth's Future*, <https://doi.org/10.1002/2017EF000632>, 2017) —Sarah Witman, Freelance Writer

Moon's Magnetic Field May Magnetize Iron That Hits Its Surface

When molten rock cools gradually, magnetic minerals within the melt align with the background magnetic field, preserving a signature of the direction and inclination of the magnetic field at the time of cooling. The temperature threshold at which magnetic signatures become stamped into the rock is called the blocking temperature.

Scientists believe that a similar process occurred naturally on the surface of Earth's Moon. Satellite data on the magnetic field of the Moon show that the lunar surface has many magnetic anomalies. Although some of these anomalies could be explained by internal lunar processes (e.g., volcanism or iron-rich dikes), others exist in places where the amount of metal contained in Moon rocks could not have produced such strong magnetic signals. Some of these hard-to-explain magnetic anomalies are located in large basins created by past impacts.

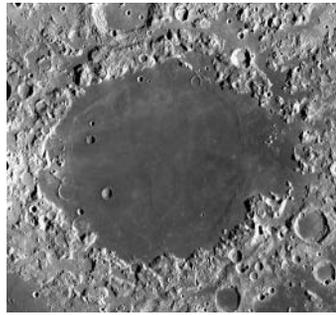
Oliveira et al. explored the idea that throughout the geologic history of the Moon, asteroids containing iron hit its surface. The force of the impact would have heated the projectiles and the targeted Moon's surface materials until they melted, creating pools in the craters the impacts left behind. As this molten material cooled down in its new environment, the Moon's magnetic field could have magnetized it. Could this pathway have caused the observed magnetic anomalies on the Moon's surface?

The team looked at magnetic field data collected by satellites scanning the Moon to estimate the magnetization of the melt sheets on craters' floors using a unidirectional magnetization model. To calculate the amount of iron metal contained in the impact melt sheets, the researchers developed a technique based on lab experiments that relates the abundance of metallic iron to magnetization, the magnetizing field strength, and the rock magnetic properties.

Assuming that the magnetized portion of the Moon's large basins is roughly a kilometer thick, the team found that, on average, the melt sheets contain roughly 0.11%–0.45% of iron metal that might have been delivered by the projectiles that formed the impact basins. These findings are consistent with past studies of Moon rocks and meteorites that have landed on the Moon and Earth, respectively.

This study not only helps scientists better understand the possibility that magnetic anomalies on the Moon were caused by iron-impregnated projectiles but also opens up the possibility that the magnetic fields of other space bodies—such as Mercury—could have been caused by external objects. By illuminating the general composition of these projectiles, the process of their impacts, and their evolution after hitting the Moon's surface, the team's results may improve future studies of planetary surfaces and structures. (*Journal of Geophysical Research: Planets*, <https://doi.org/10.1002/2017JE005397>, 2017)

—Sarah Witman, Freelance Writer



Mare Crisium, a large impact basin on Earth's Moon. Credit: NASA/LRO

Major Uncertainty in Estimates of Carbon Trapped in Soil

Soils hold the largest supply of organic carbon on Earth, triple the amount contained in the atmosphere. As the climate warms, scientists expect that microbes and roots will break down soil organic carbon (SOC) more quickly and release carbon dioxide emissions to the atmosphere at a faster rate. This process, known as soil respiration, is a crucial element in climate models. Yet global SOC databases are out of sync with field measurements, hindering efforts to model Earth's future climate, a new study finds.

Organic carbon enters the soil as plants and animals decompose, and it's exuded by living and dead microorganisms as well. The amount of SOC in any given patch of soil varies according to climate, time, and soil texture—clay-rich soil, for example, is better at retaining carbon. To estimate the distribution of SOC around the globe, scientists have created databases like SoilGrids, which predicts soil properties down to 200 centimeters on the basis of 110,000 soil profiles from around the world; the Harmonized World Soil Database (HWSD), a collection of geographic information on soil properties from inventories all over the world, down to 100 centimeters; and the Northern Circumpolar Soil Carbon Database (NCSCD), which quantifies organic carbon in soils in the permafrost around the North Pole to a depth of 300 centimeters.

Past studies have revealed that these databases often do not agree with one another or with field measurements. A new study by *Tifafi et al.* underscores that uncertainty by comparing data from SoilGrids, HWSD, and NCSCD to field measurements collected from North America, France, England, and Wales. The researchers calculated SOC concentrations down to 1 meter; soils at this depth and below are important to global climate modeling, as they often hold the greatest concentrations of SOC. They are also expected to warm at roughly the same rate as surface soils and the atmosphere.

The team found that most data sets underestimate SOC by more than 40% compared with field data, and some underestimated stocks by 80%–90%. In the Arctic regions, where SOC is rapidly being released from melting glaciers, the discrepancy between the databases and field data was even worse. Scientists urgently need to refine the statistical methods they use to predict soil composition to improve global climate models, the authors conclude. (*Global Biogeochemical Cycles*, <https://doi.org/10.1002/2017GB005678>, 2018) —Emily Underwood, Freelance Writer



Brecon Beacons mountain range in Wales. Researchers found discrepancies between global databases and field measurements of soil carbon in North America, France, England, and Wales. Credit: Agi&Pali, CC BY-NC 2.0 (<http://bit.ly/ccbync2-0>)

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Interdisciplinary

Assistant/Associate/Full Professors-Geophysics, Geodesy, Space Physics, Planetary Sciences

The Department of Earth and Space Sciences at the Southern University of Science and Technology of China (SUSTech) invites applications for tenure-track (or tenured) faculty positions at the ranks of Assistant, Associate, and Full Professors. Applicants must have earned doctoral degrees in Geophysics, Geodesy, Space Physics, Planetary Sciences or closely related fields. Successful applicants will be expected to establish a robust, externally funded research program and demonstrate strong commitment to undergraduate and graduate teaching, student mentoring, and professional services. These positions will remain open until filled.

SUSTech is a young university at Shenzhen, China (next to Hong Kong) since 2011 which is set to become a world-leading research university, to lead the higher education reform in China, to serve the needs of innovation-oriented national development and the needs of building Shenzhen into a modern, international and innovative metropolitan. These positions are created with a significant development to establish a vigorous research program in Earth and Space Sciences at SUSTech to serve the national call for China's important role in this field.

To apply send a cover letter, complete vitae with list of publications, and three names of references to [hiring@sustc.edu.cn](mailto: hiring@sustc.edu.cn), or to Dr. Xiaofei Chen, Chair Professor at Department of Earth and Space Sciences, Southern University of Science and Technology, No 1088, Xueyuan Rd., Xili, Nanshan District, Shenzhen, Guangdong, China 518055.

ASSISTANT RESEARCH SCIENTIST – (IODP Expedition Project Manager/ Staff Scientist)

The International Ocean Discovery Program (IODP) at Texas A&M University invites applications for an Assistant Research Scientist (Expedition Project Manager/Staff Scientist) in our Science Operations section. Applications in any field of geoscience pertinent to IODP will be considered although preference will be given to those with expertise that fits well with our current group.

A Ph.D. in geosciences or related field, and demonstrated on-going research experience is required. Applicants must have a demonstrated fluency in written and spoken English. Experience as a seagoing scientist, especially in scientific ocean drilling, is preferred.

This position will serve as the Expedition Project Manager to coordinate all aspects of precruise expedition planning, sea-going implementation, and postcruise activities. These duties include sailing as the IODP scientific

representative on a two-month IODP expedition approximately once every 1 to 2 years.

Individual scientific research, as well as collaboration with colleagues at Texas A&M University in fulfilling its educational mission, is required.

This position will also provide scientific advice on laboratory developments in their area of specialization including scientific implementation of downhole logging on the JOIDES Resolution. Applicants must be able to cooperate and work harmoniously with others, have the ability to be an effective team leader, and foster collaboration among diverse scientific participants. Passing a new employee medical exam and annual seagoing medical exams are a requirement of the position.

Salary will be commensurate with qualifications and experience of the applicant. This is a regular full time position, contingent upon continuing availability of funds for IODP. We will begin reviewing applications on June 30, 2018, but will continue to accept applications until candidates are selected for interviews. External applicants may apply online to the job posting at <https://jobs.tamu.edu/> with reference to Posting Number R-004291-1, attach a curriculum vita, list of published papers, statement of research interests, and names and contact information of three professional references.

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Assistant/Associate/Full Professors-Physical and biological Oceanography, marine geophysics/geology

The Department of Ocean Science and Engineering at the Southern University of Science and Technology (SUSTech) invites applications for tenure-track (or tenured) faculty positions at the ranks of Assistant, Associate, and Full Professors. Applicants must have earned doctoral degrees in marine geophysics/geology, physical oceanography, biological oceanography and ocean engineering or closely related fields. Successful applicants will be expected to establish a robust, externally funded research program and demonstrate strong commitment to undergraduate and graduate teaching, student mentoring, and professional services. These positions are created with a significant development to establish a vigorous research program in oceanography at SUSTech to serve the national call for China's important role in deep sea research and resource-oriented exploration in the world oceans. These positions will remain open until filled.



Kiel University and GEOMAR Helmholtz Centre for Ocean Research Kiel intend to attract more qualified women for professorships.

The Faculty of Mathematics and Natural Sciences at Kiel University, Germany and GEOMAR Helmholtz Centre for Ocean Research Kiel jointly invite applications for a

Professorship (W 3) in Theoretical Oceanography

The Professorship is based at GEOMAR Helmholtz Centre for Ocean Research Kiel and assigned to the Research Unit 'Theory and Modelling' within the Department 'Ocean Circulation and Climate Dynamics'.

We are seeking a dynamic individual who will carry out vigorous, internationally recognized research in the field of ocean and atmosphere dynamics and who will contribute to the understanding of ocean-atmosphere interactions. Applicants should have a strong research record in geophysical fluid dynamics, enabling them to enhance the understanding of processes ranging from 3-D turbulence to the large-scale circulation. This particularly includes the representation of ocean mixing in models and the combination of modelling and observations. The successful candidate can build on a well-established cooperation between modelling and observational research groups within the department. Particular research foci could be theoretical studies that are the basis for parameterizations and innovative solutions in ocean and climate modelling as well as data analysis. The scientific work should also facilitate interdisciplinary cooperation with other departments at GEOMAR and within the Kiel Marine Sciences.

The professor will teach within the B.Sc. program „Physik des Erdsystems“ and the M.Sc. program „Climate Physics“ in the field of ocean and climate physics with focus on theoretical oceanography and geophysical fluid dynamics. Corresponding teaching experience is required. We expect teaching in English and willingness to teach in German within 3 years.

The position has been opened with respect to Art. § 61 and § 63 Section 1 of the Higher Education Act of the State of Schleswig-Holstein. The teaching commitment currently is 4 semester hours per week. For additional information about the position please contact Prof. Dr. Peter Brandt (pbrandt@geomar.de). Detailed information about the GEOMAR Helmholtz Centre for Ocean Research Kiel can be found under www.geomar.de.

Kiel University and GEOMAR Helmholtz Centre for Ocean Research Kiel wish to increase the number of female scientists in faculty positions and encourages applications from qualified women. Female applicants will be given priority if their qualifications and achievements are equal to those of male applicants. Applications from scientists with disabilities will be given priority in case of equal qualifications. We explicitly encourage candidates with a migration background to apply. Please refrain from submitting photographs.

Applications in English including curriculum vitae, certificates of academic degrees, lists of publications, teaching experience and past and present third-party funding, statement on previous and future research interests and teaching plan together with private and academic mailing and e-mail addresses and telephone number should be submitted in electronic form in a single pdf-file (smaller than 20 MB) by **July 6, 2018** to The Dean, Faculty of Mathematics and Natural Sciences, Kiel University, D-24098 Kiel, Germany (berufungen@mnf.uni-kiel.de).

SUSTech is a young university (established in 2011) in Shenzhen, China (next to Hong Kong), which is set to become a world-leading research university and to lead the higher education reform in China. It also will serve the needs of innovation-oriented national development and the needs of building Shenzhen into a modern, international and innovative metropolitan.

To apply, please send a cover letter, complete vitae with list of publications, and three names of references to hring@sustc.edu.cn, or to Dr. Y. John Chen, Chair Professor and chair of the Department of Ocean Science and Engineering, Southern University of Science and Technology, No 1088, Xueyuan Rd., Xili, Nanshan District, Shenzhen, Guangdong, China 518055.

Cluster Hiring in Geo-Bioinformatics/ Environmental Genomics and Organic Biogeochemistry

The Southern University of Science and Technology (known as SUSTech or SUSTC) (<http://www.sustc.edu.cn/en>) was founded in 2011 with public funding from Shenzhen, a dynamic city that has been viewed as the vanguard of China's development in science and technology. The goal of SUSTech is to become a top-tier international university that excels in interdisciplinary research, talent development and knowledge discovery.

Siting at the mouth of the Pearl River flowing to the South China Sea, the newly born (2015) Department of Ocean Science and Engineering at SUSTech aims to become a major player in education and research in ocean sciences in China. It will be housed in a brand new building on the beautiful SUSTech campus, with ample laboratory space that is equipped with the latest technology for conducting cutting edge research. The 5000 ton R/V Shenzhen is in the planning stage of construction, which is expected to be built by 2022.

The Institute for Geo-Omics Research (TIGOR) at SUSTech aims to become an open platform for world class research in microbial oceanography and geomicrobiology, and an inviting home for domestic and overseas scientists to exchange ideas and together advance the field of ocean sciences. In the early stage of TIGOR's growth, the priority will be to build two research strengths: Geo-Bioinformatics/Environmental Genomics and Organic Biogeochemistry. The integration of these strengths will allow us to study systematically the evolution of life on early Earth, microbial ecology impacted by human activity, mechanisms of bio-organic interactions in the deep ocean, and fundamentals of biogeochemistry (e.g. lipid biosynthesis and bio-fractionation of isotopes of life-essential elements).

In Geo-Bioinformatics/Environmental Genomics hiring, we seek

highly qualified candidates (at the assistant or associate professor levels) who are able to apply bioinformatics techniques (metagenomics, multi-omic integrative analysis, in silico lead discovery from microbial metabolites and computational biology algorithm/server development) to analyze data from the next-generation sequencing and other high-throughput sequence profiling to address fundamental questions mentioned above. Candidates with strong ecological backgrounds are particularly encouraged to apply.

In Organic Biogeochemistry hiring, we seek highly qualified candidates (at the assistant, associate or full professor levels) with strong skills in mass spectrometry and isotope geochemistry. The candidates are expected to apply GC-MS, LC-MS (Orbitrap or ion mobility Q-TOF), FT-ICR MS, or AMS to address questions mentioned above.

Highly competitive salaries and benefit packages will be provided to the hired candidates, who may also be eligible for additional government support such as the Shenzhen City's Peacock Program and the Chinese Government's One Thousand Talents Program (http://www.sustc.edu.cn/en/faculty_en).

Applicants are required to have a Ph.D. degree in earth sciences, biology, chemistry, computer science, or related disciplines. Post-doctoral experiences are preferred but not required. Candidates must have a proven and consistent track record of high-quality scientific publications and good communication skills. Chinese and English are required languages for teaching. To apply, please submit the following material electronically to wangy9@sustc.edu.cn: 1) Cover letter; 2) Curriculum vitae (with a complete list of publications); 3) Statement of research and teaching interests; 4) Reprints of three recent papers; and 5) Names and contact information for three references. All positions remain open until filled.

Data Analyst

The Data Analyst will be responsible for focusing on flood analysis and development initially, with planned vectoring to data intelligence analysis duties, for both science and non-science applications to support property and non-property business segments.

A data analyst will need to have familiarity with scientific data analysis, data inference techniques and programming. Will have a general background in physical and mathematical sciences, applied data intelligence analysis, and statistical data mining. Preferred individual in this role would also have capabilities in GIS spatial analytics and development of disruptive data technologies. ArcGIS, R, Python application and language familiarity.

JOB ACCOUNTABILITIES

• Adapting and running geophysical models, supporting senior scientists in the diagnosis and interpretation of model-based results.

• Assisting scientists, senior scientists and management in the manipulation of data, systems analysis and database administration.

MINIMUM REQUIREMENTS

• 3 to 5 years of experience in an applied science, preferably the geophysical sciences

• A data analyst will need to have familiarity with scientific data analysis, data inference techniques and programming.

• General background in physical and mathematical sciences, applied data intelligence analysis, and statistical data mining.

• Familiarity with UNIX/Linux development environment.

• Comfortable working with large datasets to support analysis objectives.

• MatLab, Python experience.

Familiarity with R or similar languages is a plus.

• Ability to understand, compile and manipulate finite difference geophysical models. Familiarity with ADCIRC storm surge model is preferred.

• Software development skills. Seasoned diagnostic skills for quality assurance.

• Preferred individual in this role would also have experience and skills in GIS supported spatial analytics and data mining techniques and data analytics technologies.

• Proven ability for collaborative work on technical project teams. Candidate must have a track record of providing valuable input under the guidance of a principal investigator.

Email Applications: CareersUSA@renre.com

Faculty Positions available in the School of Environmental Science and Engineering

The Southern University of Science and Technology (known as SUSTech or SUSTC) (<http://www.sustc.edu.cn/en>) was founded in 2011 with public funding from Shenzhen City. A thriving metropolis of 20 million people bordering Hong Kong, Shenzhen has often been referred to as the "Silicon Valley of China" with strong telecommunication, biotechnology and pharmaceutical sectors. Widely regarded as a pioneer of higher-education reform in China, SUSTech aims to become a top-tier international university that excels in interdisciplinary research, talent development and knowledge discovery. English is the language of instruction.

The School of Environmental Science and Engineering at SUSTech was established in 2015 to provide a new platform for performing cutting-edge research and for training the next generation of environmental scientists, engineers and managers who are interdisciplinary, innovative and

global-thinking. Currently the school has 28 full-time faculty and research staff, including two academy members, eight recipients of the Thousand Talents Program, and four recipients of the young investigator awards by the National Natural Science Foundation of China (<http://ese.sustc.edu.cn/en/>). The school is planning to fill two dozen more tenure-track/tenured positions over the next few years. In addition to a generous startup package to each tenured or tenure track faculty position, the school was recently awarded a 3-year enhancement grant of 50 million RMB (~7 million USD) to strengthen its core areas of research. Moreover, the school is in line to receive 120 million RMB (~18 million USD) for research instrument capability development.

Applications are invited for faculty positions at all ranks. Areas of interest include, but are not limited to, water pollution and treatment, environmental (soil, groundwater, ecosystem) remediation and restoration, hydrology and water resources engineering, biogeochemistry, environmental microbiology, atmospheric chemistry, air pollution control, air quality engineering, solid waste treatment and utilization, environmental health risk assessment and interventions, remote sensing of the environment, macroecology and global change, and environmental management. Highly competitive salaries and benefit packages will be provided to tenure-track/tenured faculty. New hires may also be eligible for additional government support such as the Shenzhen City's Peacock Program and the Thousand Talents Program (http://www.sustc.edu.cn/en/faculty_en).

Applicants are required to have a Ph.D. in environmental science and engineering, earth and atmospheric sciences, or related disciplines. Post-doctoral experience is preferred but not required. Candidates must have a proven and consistent track record of high-quality scientific publications and good communication skills. To apply, submit the following materials electronically to iese@sustc.edu.cn: 1) Cover Letter; 2) Curriculum Vitae (with a complete list of publications); 3) Statement of research and teaching interest; 4) PDFs of three recent publications; and 5) Names and contact information for 3-5 references. All positions remain open until filled. For additional information, please contact Xiaoli Wang (email: wangxl@sustc.edu.cn, phone: +86-755-8801-0821).

NASA Postdoctoral Program (NPP)

The NASA Postdoctoral Program (NPP) supports NASA's goal to expand scientific understanding of Earth and the universe in which we live.

This announcement reflects recent increases to the NPP annual base stipend and the annual travel allowance provided to fellows.

The NASA Postdoctoral Program offers US and international scientists the opportunity to advance their research while contributing to NASA's scientific goals. The NPP supports fundamental science; explores the undiscovered; promotes intellectual growth; and encourages scientific connections.

Engage in NASA research in Earth science, planetary science, heliophysics, astrophysics, aeronautics and engineering, human exploration and operations, space bioscience, and astrobology.

Details:

UPDATED! Annual stipends start at \$60,000, with supplements for high cost-of-living areas and certain degree fields

UPDATED! Annual travel budget of \$10,000

Relocation allowance

Financial supplement for health insurance purchased through the program

Appointments renewable for up to three years

Approximately 90 Fellowships awarded annually

Available Fields of Study:

Aeronautics, Aeronautical or Other Engineering

Astrobiology

Astrophysics

Biological Sciences

Cosmochemistry

Earth Science

Heliophysics Science
Interdisciplinary/Other
Planetary Science
Technology Development
Available NASA Centers:
Ames Research Center
Armstrong Flight Research Center
Glenn Research Center
Goddard Institute for Space Studies
Goddard Space Flight Center
Jet Propulsion Laboratory
Johnson Space Center
Kennedy Space Center
Langley Research Center
Marshall Space Flight Center
NASA Astrobiology Program
NASA HQ

Solar System Exploration Research Virtual Institute

Stennis Space Center

Wallops Flight Facility

NOTE: Not all centers participate in every application round... please refer to the website for current opportunity locations

Eligibility:

US citizens, Lawful Permanent Residents and foreign nationals eligible for a J-1 visa as a Research Scholar Recent and Senior-Level PhD recipients

Application Deadlines

Three each year—March 1, July 1, and November 1

To learn more about specific opportunities and to apply, please visit: <https://npp.usra.edu/opportunities/>



THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

Faculty Positions Department of Ocean Science

The University is a world-class research institution with over 600 faculty members whose research ranges from science to engineering, business and social sciences. It is ranked No. 1 in Asia by QS World University ranking in 2011-2013. Located in the Clear Water Bay area, HKUST's campus has a magnificent ocean view and is widely known as one of the most beautiful campuses in the world. The city of Hong Kong ranks among the most international and dynamic cities.

The University has set up a new Department of Ocean Science under the School of Science in February 2018. The new department will primarily focus on marine ecology (existing strength), oceanography, and ocean technology covering coastal region to deep-sea. The Department is seeking applications for tenure-track positions at the ranks of Assistant Professor or above in physical, chemical, biological oceanography, ocean sensor and sensing technology and ocean data science.

Applicants should have a PhD degree in any of the above fields, preferably with at least 2 years of post-doctoral experience. Successful candidates should have strong research track records. They are expected to establish an independent research program and contribute to the missions in undergraduate and postgraduate education of the newly established Department of Ocean Science. The medium of instruction is English.

HKUST offers internationally competitive salary commensurate with qualifications and experience. Fringe benefits include annual leave, medical and dental benefits. Housing benefits will also be provided where applicable. Initial appointment for Assistant Professor/Associate Professor will normally be on a three-year contract, renewable subject to mutual agreement. A gratuity will be payable upon successful completion of contract.

Application Procedure

Application materials including a cover letter, detailed curriculum vitae, research accomplishment and proposal (maximum 3 pages), three representative publications and teaching statement (maximum 1 page) should be sent to the Chair of Search and Appointments Committee (ocesearch@ust.hk). Applicants should arrange at least 3 letters from referees directly to the Chair of Search and Appointments Committee to complete their application. The recruitment process will continue until all positions are filled.

(Information provided by applicants will be used for recruitment and other employment-related purposes only.)

Included Benefits:

UPDATED! Annual stipends start at \$60,000, with supplements for high cost-of-living areas and certain degree fields

UPDATED! Annual travel budget of \$10,000

Relocation allowance

Financial supplement for health insurance purchased through the program

Appointments renewable for up to three years

Approximately 90 Fellowships awarded annually

Faculty Position Earth Systems Science, Rensselaer Polytechnic Institute Dept of Earth and Environmental Sciences

The Department of Earth & Environmental Sciences at Rensselaer Polytechnic Institute in Troy, NY invites applications for a tenure/tenure-track position at the assistant, associate or full professor level in Earth Systems Science. The E&ES Department research areas include experimental, analytical and environmental geochemistry, petrology of Earth's systems, environmental informatics, solid Earth geophysics, paleoclimate, origins of life and geomicrobiology. We are seeking applicants whose research will complement and grow these strengths and whose research programs address fundamental problems in Earth Systems science. Disciplinary areas that are of particular interest include, but are not limited to, natural systems and environmental geochemistry, early Earth environments, geochemical proxies for interpreting ancient environments, global ocean-atmosphere-geosphere interactions, and planetary evolution. Additionally, research programs that address fundamental questions in hydrogeology and/or remote sensing will serve to expand the Earth Systems science program at RPI.

Successful candidate will have duties that include teaching graduate and undergraduate courses in the Department of Earth & Environmental Sciences, engaging in the Environmental Sciences undergraduate program, developing and maintaining robust programs of research and scholarship, and providing service to the department, the School of Science, and to Rensselaer

The successful candidate will have a Ph.D. or foreign degree equivalent in geoscience or related discipline, along with the ability to demonstrate, through accomplishments, a record of excellence in research and scholarship, evidence or the promise of future distinction in high quality educational activities including teaching and advising, and a proven commitment to professional service. The rank at the time of hire will be commensurate with the candidate's experience and accomplishments.

We welcome candidates who will bring diverse intellectual, geographical, gender, and ethnic perspectives to Rensselaer's work and campus communities. Rensselaer Polytechnic Institute is an Affirmative Action/Equal Opportunity, Race/Gender/Veterans/Disability Employer.

Apply at: <http://hr.rpi.edu/>

Ocean Science

Applied Physics Laboratory – Research Associate

The Applied Physics Laboratory at the University of Washington (APL-UW) is seeking Post-doctoral Research Associates with research interests in Oceanography, Polar Science, Remote Sensing, Environmental Acoustics and Ocean Engineering. These are full-time (100% FTE) appointments, with expected terms of two years subject to satisfactory performance and availability of funding.

Positions are not project-specific; each applicant is expected to define his/her research goals within the broad program areas of the participating APL departments: Air-Sea Interaction & Remote Sensing (AIRS), Acoustics Department (AD), Ocean Engineering (OE), Ocean Physics Department (OPD), and the Polar Science Center (PSC). All UW faculty engage in teaching, research, and service. Successful applicants must hold a recent (no more than 4-years) PhD or foreign equivalent in order to assume a post-doctoral position.

More information: <http://ap.washington.edu/ahr/academic-jobs/position/aa27897/>

Applicants asked to submit electronically:

- (1) A curriculum vitae,
- (2) A publication list,
- (3) A brief research proposal (no more than 5 pages, double-spaced, excluding bibliography and figures) describing research to be pursued during a two-year tenure at the University of Washington, and
- (4) The names of four individuals who can provide a letter of reference.

In addition, a letter of support from a mentor in one of the participating departments (AIRS, AD, OE, OPD, PSC) is strongly encouraged. Further information on current research at APL, by department and principal investigator, can be found at: <http://www.apl.washington.edu/departments/departments.php>

Applications should be submitted via email:

Dr. Kevin Williams
Sr. Principal Physicist, Acoustics Department Chair, Liaison of Science & Engineering Group
williams@apl.washington.edu

Tier 2 CRC in Physical Oceanography

The Department of Oceanography at Dalhousie University is seeking appli-

cants for a Tier 2 Canada Research Chair (CRC) in Physical Oceanography. Applicants must hold a PhD in Physical Oceanography or a closely related discipline, and have a strong record of research excellence. The applicants' research should address ocean dynamics on a range of temporal and spatial scales, and it should complement the existing research activities by physical oceanography faculty in the Department, e.g., ocean models and observational analyses, shelf and deep ocean circulation, nearshore processes, air-sea interactions, climate variability, ocean acoustics, and mixing. Interests in cross-disciplinary oceanographic research are an asset.

The successful applicant will be appointed to a tenure-track position at the rank of Assistant or Associate Professor. The anticipated start date is 1 July 2019, or as negotiated. The application should include a detailed curriculum vitae, a two- to three-page statement of research interests, three representative publications, the names and contact information of three references, and a completed Self-ID questionnaire (www.dal.ca/becounted/selfid). Review of applications will begin on 4 June 2018 and will continue until the position is filled. Please send the complete application as a single pdf to:

Dr. Katja Fennel
Search Committee Chair, Tier 2 CRC in Physical Oceanography
POsearch@dal.ca

The CRC program was established to attract outstanding researchers to Canadian universities (see www.chairs.gc.ca for more information). Dalhousie University encourages applications from Aboriginal people, persons with a disability, racially visible persons, women, persons of minority sexual orientations and gender identities.

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Postcards from the Field



Hej! Hej! (Hello! Hello! in Swedish)

We're out here in Stordalen mire, a peatland underlain by discontinuous permafrost in the Swedish Arctic. Look at us, basking in Arctic rays and avoiding the plagues of mosquitos. Or not.

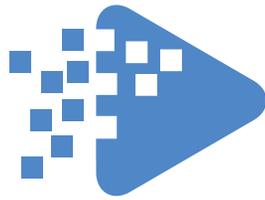
Here we're processing cores taken in these peatland lakes to help understand how aquatic vegetation affects methane dynamics and how this might affect global carbon budgets with increasing permafrost thaw in these northern peatlands.

Hejdå! (Good-bye!)

Best wishes and warm regards from the field.

—**Christopher Horruitiner**, Department of Earth Sciences, University of New Hampshire, Durham

View more postcards at <http://americangeophysicalunion.tumblr.com/tagged/postcards-from-the-field>.



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